Students’ Conceptions of Statistics: A Phenomenographic Study

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Journal of Statistics Education Volume 10, Number 2 (2002),  
ww2.amstat.org/publications/jse/v10n2/reid.html

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Key Words: Curriculum development; Student learning; Student work.

Abstract

This paper reports on the results of an empirical study of students’ conceptions and understanding of statistics. Six qualitatively different conceptions are described, ranging from fragmented to inclusive views. Students expressing the more inclusive and holistic conceptions approach their study of statistics through a focus on ‘higher-order’ statistical thinking. Students expressing limited and fragmented views may not be able to understand the complexity or applications of the discipline. This paper describes the use of a qualitative methodology - phenomenography - that aims to explore the qualitatively different ways in which a group of people experience a specific phenomenon, in this case statistics. It also describes an overarching framework, the "Professional Entity," that relates students’ understanding of statistics and their perceptions of working as a statistician. Investigating and describing the ways in which students learn statistics, how they understand statistics, and how they perceive their own work will enable teachers to develop curricula that focus on enhancing the student learning environment and guiding student conceptions of statistics.

1. Background

Teachers of statistics expect that students will come to understand the unique qualities of their chosen discipline through the course content, class activities, and assessment or examination tasks. Traditionally, teachers have focused the development of curriculum on the content of the discipline and expect that students will come to understand it in some way as time passes. More recently, the role of assessment as a
determinant of student learning has been highlighted, in tertiary education generally (Ramsden 1992) and in statistics education in particular (Garfield and Gal 1999). Batanero (2001) points out that research in statistics education has only rarely investigated the "emotional components" related to learning statistics; one important exception is the work of Gal and Ginsburg (1994). Investigating the affective dimension of statistics learning adds another dimension to the development of effective pedagogy in statistics.

Exploring how students report understanding statistics, and then using this evidence for curriculum development is counter to traditional views. For instance, Weinberg and Abramowitz (2000, paragraph 2) suggest that “For teachers to be effective they must provide experiences and opportunities for students to reach the goals they have set for them.” This quote is salient in indicating that students learn through experience, but focuses on the teachers’ experience rather than the students’. Indeed, Weinberg and Abramowitz (2000, paragraph 4) go on to say that “Our challenge is to find ways of presenting information to our students so that it is accessible, relevant, applicable, and even vital to their own areas of interest” [emphasis added]. Yesilcay (2000) reports enhanced student learning through the use of projects in their area of interest, writing that “students tend to learn more by doing such a project than in any regular coursework. The project is motivating and gives students a feeling of working in an almost real-life environment on a real problem.” Of course, “area of interest” is not necessarily dictated by students’ majors: in fact, Yesilcay’s students (and those in our study) were majoring in mathematics or statistics.

Recent research in higher education generally (Prosser and Trigwell 1999), and in specific subject areas (for example, Reid 2001, in music; Petocz and Reid 2001, in statistics) suggests that students understand their chosen disciplines in a variety of different ways, and hence approach their learning in different ways. In the area of mathematics, Crawford, Gordon, Nicholas, and Prosser (1998) suggested that there is a relationship between mathematics students’ understanding of mathematics, the approach they take to learning mathematics, and the quality of their learning outcomes.

A dilemma arises: as teachers and researchers in statistics, we believe that we know what is critical for students to learn from our own experience of being learners and statisticians. However, students’ experience and understanding of statistics, and professional work that involves statistics, is likely to be more limited. Developing teaching and learning activities that support and develop students’ learning of statistics from their own perspective can be problematic. delMas et al. (1999) write that “Researchers and educators have found that statistical ideas are often misunderstood by students and professionals. In order to develop better statistical reasoning, students need to first construct a deeper understanding of fundamental concepts.” Research in other areas suggests that there is a strong link between students’ understanding of their discipline in a work context and the way they then go about learning in their discipline (Prosser and Trigwell 1999; Marton and Trigwell 2000; Reid 2001). An obvious solution to the dilemma is to first ask students of statistics how they understand statistics and then use this information to develop learning activities and assessment tasks that encourage students toward the highest learning outcomes.

In the research study reported here we have done just that. We have asked students to describe to us how they understand statistics: we have then organised their responses into a hierarchy of conceptions. Batanero, Garfield, and Ottaviani (2001) acknowledge the importance of qualitative, as well as quantitative, methodologies for investigating students’ learning in statistics. This paper describes the use of a qualitative methodology - phenomenography - that is often used in educational research. This method aims to describe the qualitatively different ways that people understand or experience a phenomenon. It is unlike some other qualitative methods in that it uses open-ended, in-depth interviews to enable the participants to explore their own experience, and then uses the total group experience to highlight the variation found within the group. Analysing and describing the different ways students understand statistics is a departure point for the development of a student-centred curriculum.
Curriculum is usually developed from the knowledge base of the teachers, the strategic requirements of the university and the demands of relevant industries (Jenkins 1995; Bowden and Marton 1998; Toohey 1999), and the ways that students understand the discipline are often assumed. Describing the different ways that students experience, or understand, statistics is vital for the continued, informed development of statistics curricula. Taking this approach, the needs of the students assume primacy and educators are better able to assist them in developing understanding of the subject, for example by developing appropriate learning materials (see, for example, Wood and Petocz 2002). Additionally, future research on student learning can build on a knowledge of the hierarchy of statistics students’ conceptions of their subject. A recent study by Boulton-Lewis et al. (2001) identifies such a hierarchy and tracks the development of students’ approaches to learning in response to their learning experiences. A study by Ho et al. (2001), describes how the range of teachers’ conceptions of teaching in higher education (in a variety of subject areas) formed the basis of an intervention that led to an increase in students’ higher-order learning.

In the sections that follow, we describe students’ conceptions of the discipline area of statistics, and how these disciplinary views may be related to their perception of professional work as a statistician. (We have previously described student conceptions of learning statistics, and how this affects their conceptions of their lecturers’ teaching in Petocz and Reid 2001 and 2002a.) The use of the word "conception" is deliberate, as it suggests that we describe a relation between the students and statistics which is constituted through their personal experiences and understanding of statistics.

2. The Method of Phenomenography

Phenomenography looks at how people experience, understand, and ascribe meaning to a specific situation or phenomenon (Marton and Booth 1997). The outcome of a phenomenographic study is a hierarchical set of logically related categories, from the narrowest and most limited to the broadest and most inclusive. These categories and the relations between them provide the outcome space for the research. The categories describe the qualitative differences between one conception of statistics and another. Phenomenography can be seen to richly describe the object of study through an emphasis on describing the variation in the meaning that is found in the participants’ experience of the phenomenon. The categories are usually reported in order of their inclusivity and sophistication, and they are defined by their qualitative difference from the other categories. Phenomenography examines the experience of each participant and recognises that each person’s experience is an internal relation between the subject and the object, in other words, between the participant and the phenomenon. However, it is the structure of the variation across the group that emerges through iterative readings of descriptions of the experience.

Phenomenography is a qualitative orientation to research that takes a non-dualist perspective and is often used to describe the experience of learning and teaching (Bruce and Gerber 1995; Prosser and Trigwell 1997). This means that 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. This method has also been used to identify different ways of experiencing academic disciplines (rather than the experience of teaching or learning in the discipline). For instance, Crawford, Gordon, Nicholas, and Prosser (1994) looked at variation in the way students understood mathematics, Lyons and Prosser (1995) looked at variation in the way students understood electricity, Hazel and Prosser (1994) looked at variation in the way students understood photosynthesis, and Davey (2001) looked at the way nurses understood competency in neo-natal nursing. Each of these studies has had the extended outcome of informing curriculum change to develop quality student-focused learning environments.

Data are typically collected through a series of in-depth, open-ended interviews that focus on allowing
each person to fully describe their experience (Bowden 1996). Analysis of written materials describing the participants’ understanding of a phenomenon has also been used (Marton and Saljo 1976; Crawford et al. 1994). In our research project we interviewed 20 students from a first-year statistics class and a third-year class in regression analysis. All these students were undertaking a degree in mathematics, with possible specialisations in statistics, finance or operations research. The interviews were transcribed verbatim to yield 54 pages (over 33000 words) of transcripts, and these formed the raw material for our study. The study was approved by the Human Research Ethics Committee of the University of Technology, Sydney, and the illustrative quotes that we use from the interviews are labeled with pseudonyms to avoid identification of individual students.

In a phenomenographic study, the questions posed are designed to encourage the participants to think about why they experience the phenomenon in certain ways and how they constitute meaning of the phenomenon. In this case, students responded to the key questions/statements:

“What do you understand statistics to be about?”

“What do you understand by the term statistics?”

“Tell me what you think statistics is.”

“What is statistics?”

Since the intention of phenomenographic research is to report on the variation that emerges from the whole group’s understanding of the phenomenon - in this case, the notion of statistics - the range of questions was designed to focus students’ awareness on different aspects related to their experience of statistics. These questions were followed by probing questions which responded to the students’ answers.

Each interview was conducted by one of the principal researchers who did not have academic involvement with the students or by the research assistant for the project. According to the protocol set out in the ethics approval for this study, students were selected at random by the research assistant from the first and third-year class lists. These students were invited to participate in the project and were aware of the research questions and aims. The interviews lasted between 30 minutes and 1 hour, and were concluded when the student indicated that they had satisfactorily explored the research questions. It can be seen from the questions and statements listed above that one focus of the study was an exploration of students’ understanding of statistics. The first question focused on the students’ global understanding of the idea of statistics and responses to this question were followed by other questions to clarify their answers. The later questions were aimed at allowing students to describe their understanding of statistics fully. Another component of the study was an exploration of student learning of statistics (reported in Petocz and Reid 2001) and the connection with students’ expectations of their lecturers’ teaching (described in Petocz and Reid 2002a).

The aim of the analysis is to focus on the meaning that is found within the transcripts rather than hunting for evidence of predefined categories. In this sense phenomenographic analysis is interpretivist and emergent. Thus, categories describing the students’ conceptions of statistics were developed on the basis of the range of responses observed in the transcripts. The researchers needed to familiarise themselves with the content of all the transcripts to become aware of the variation that emerges from the whole data set. Transcripts of interviews were read by both authors (a rather lengthy but important process). One member of the team was a subject expert and the other was experienced in phenomenographic analysis. Categories describing the variation were suggested, refined and checked by repeated reading, and the final categories were confirmed by identification of appropriate quotes in the transcripts. The categories listed below are inclusive and hierarchical. Each category is supported by some succinct quotes from the
transcripts which are illustrative of the conception and have been selected for their brevity and clarity. It is important to note, however, that the quotes used are illustrative of the conceptual categories, and that the aim is not to put any particular student into a specific category. Each individual quote is not necessarily indicative of the meaning of the category, but merely supportive, and the richness of each category is defined by the whole set of transcripts. Each of the categories comprises two elements: what the student focuses on in the subject, and their related approach to the subject (the "what" and "how" described by Marton and Booth 1997).

3. Categories Describing Students’ Conceptions of Statistics

Our analysis of the transcripts identifies six qualitatively different ways in which students understand statistics. These different ways of understanding statistics range from limiting to expansive views. We use the term ‘limiting’ to indicate that students who describe such views seem unable to describe any characteristics of more integrated and expansive views. This means that these students may only be able to focus their attention within their learning environment on fragmented and unrelated issues. Basically, such students miss the point. Albert (2000, paragraph 6) suggests that “Students may memorize procedures for correctly solving questions of different types without really understanding the underlying statistical concepts.” A statement such as this lends validity to the idea that some students focus on elements that seem irrelevant to the real meaning and use of statistics. Conversely, students who can describe the more integrated and expansive views are able to make use of characteristics throughout the whole range as a means to further their own, already sophisticated, understanding. We have indicated the focus levels in a hierarchy that is integrated with the conceptions listed below.

A focus on techniques

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 which involves using "boring calculations," "numbers," or "probability." (Students expressing this conception may describe statistics using the unit name(s) of the subject(s) they are involved in, for instance, "Statistics 1.")

   Kim: *Statistics is just like accounting, just like accounting sometimes. Like, just like count something, and find something wrong and something like that, just like math. It is just like counting something. Just like accounting. ... We learning like, analyse, like analyse the data, like consult the reports for the answer, the solving, like analyse the data or something like that for the assignment or something like that. And the tutorial.*

   Lee: *What do I think statistics is? It is a very interesting subject. I like it. It is to do with numbers all the time isn’t it? It is making things logical, I think.*

   Pat: *I think it is pretty interesting, like probabilities, I like probability.*

   Helen: *I didn’t really like the idea of statistics because at first I thought how boring it would be. We touched on it slightly when I was in Year 10, and I decided that maybe I wouldn’t enjoy doing all those calculations and things.*

   Julie: *Calculation, it can be used to help with the calculations. I think you can use it in various ways, like it’s a short cut to finding out various things and stuff, like in corporations and that stuff, working out, like, percentages and things, and accumulations. Like, it gives you a head start to
work out what’s going to happen, and what you think is going to happen, and what’s more likely to happen.

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, regression. This conception is like Conception 1, as students focus on fragments, but is unlike Conception 1 in that students describe the fragments in statistical rather than mathematical terms.

Lee: (When you are using Minitab®, what do you find it useful for?) For graphs, I really like it, different colours. (And why are graphs important to you?) I find it easier to understand than all the numbers in there. All the numbers do not make sense to me. Like t value, all the numbers don’t mean anything to me unless I see the graph and I can see there is the outlier, it is observations like that when I look at them.

Alex: Statistics analyses data and in business always uses some data collecting. From statistics you can analyse the data and use the information from that.

Tran: When I did Stats 1, I had no idea. I find it interesting in Stats 2 because I did it better. I like to use the computer programs like Minitab, now I am doing Time Series, it is also about Regression. I found it very interesting. It is not related to any other maths subject or any other finance subject. It is finding the relationships, like in between the dependent and independent variables, but this doesn’t relate to any other subjects. The only thing I know about stats is regression analysis. I find the probability a bit hard.

Lily: Yeah, well in simple terms, it’s just plotting out a set of points and getting a line of best fit, kind of like that. Looking at data and trying to find a relationship between two or more variables.

Note that Alex’s view of "analysing data" seems to imply a single statistical technique (and this is supported by other parts of the transcript), rather than the broader Conception 4 that we present later. Tran’s listing of the courses studied implies a view of each of them as a separate statistical technique.

3. **Statistics is a collection of statistical techniques.**

In this conception students describe statistics as a collection or set or "stockpile" of different techniques that can be used at some time to deal with data. This conception is similar to Conception 2, with the difference that students accumulate and are aware of a range of techniques, rather than relying only on one. They often describe statistics by listing these techniques.

Lily: So you’ve got to pick up, I don’t know, just the basics, like good techniques, like, I think techniques are important. It is not always what you learn but how you approach problems, like if you are doing it stepwise like, this is the problem, you analyse it this way or that way or sometimes you do whatever. Like sometimes you do it like a method ... the way you approach problems, like basic steps to do so you always get to one level. You are never going to get a problem you don’t know what to do with, so long as you can get half way through it.

Emma: Recognising certain things that make the questions different. So analysing different sets of data and what to look for, to divide them into "this is how you treat this problem," sort of thing. So specific things that we are told, that we are taught to look for in the data to know to treat it this
way or that way or things like that. So I think the more examples I do, the more I think I am experiencing all the different problems and ways of doing things out there, so I try to do as many as possible because I know that there are just, things change from problem to problem. So that is way I try to do as many as possible. I think that is one of the important things. And I think I get a lot out of doing that huge range or types of problems. I think the worst thing you can do is focus on the theory and do one or two questions because a slight change in the problem and you just won’t know what you are doing.

There is a quote from Lily’s transcript illustrating Conception 2 as well as Conception 3: different parts of her transcript show a view of statistics as single techniques, while other parts imply a view of a collection of techniques. This gives evidence of the hierarchical nature of phenomenographic categories where participants who express their experience within a specific conceptual category can also use characteristics of less integrated conceptions when their perception of the situation demands.

These first three categories are cumulative categories. Each category is different from the previous one as more statistical techniques are included in the students’ understanding of statistics. They are all similar in that they focus on technical aspects of statistics but do not make a relation between the techniques and their use in the interpretation of data.

Often teachers will inadvertently encourage this view of statistics by treating statistical ideas as separate elements that are gradually added to as the semester progresses, such as "displaying data" or "collecting data," followed by "probability models" and then the various components of inferential statistics (such as one-sample t-tests and two-sample t-tests). The way courses are structured gives an indication to students about what is important and valued.

The next conceptions, 4 and 5, are quite different, in that the students clearly define the relationship between statistical techniques and the use of such techniques to interpret data. In this sense, Conceptions 4 and 5 focus on something broader than statistical techniques, and represent a qualitative change from the previous conceptions.

**A focus on using data**

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. Students explore different relationships found in the data and use these relationships to draw conclusions about the data. Here, students describe statistics using the techniques characteristic of conceptions 1-3, but consider these techniques to be part of a coherent whole, and aim to analyse and interpret a set of data.

Emma: *Just sort of taking companies’ data bases and looking at it, and analysing it, just finding out the marketing strand they should be focusing on, and all that sort of stuff, and that is what I see as a statistician. I think that would be really interesting, to be basically a market analyst or just, I am interested in looking at the data and finding things out from it, running it through different software programs is what you use generally. Hopefully I will gain an understanding of the stats behind the software I will be using in my job. Basically, I think of it as the analysis of data to get knowledge from the data. In a sentence that is what I would say. It is just the analysis of a set of data, or multiple sets of data, in order to tell you something about what you are analysing.*

Danny: *It is making sense of data, of taking information and making some sense of it that is useful,*
well you would hope that it is useful, and that it helps explain how things are and why things work.

Melissa: Transforming data into something you can read, something you can see in the form of graphs, finding tests to prove hypotheses if they are right or wrong. I guess basically interpreting data into a visual base and finding tests to prove it, seeing what is happening. Being able to forecast, being able to come up with a model, and you actually have to apply it in the future, that’s the most important thing I have learnt about using it.

Emma’s transcript is unusual, in that it shows that she understands statistics in a more inclusive way when she is anticipating future work as a statistician. However, in terms of the requirements of her university studies, she sees statistics as a collection of techniques, as shown by her quote in Conception 3. Melissa, on the other hand, seems to be expanding her awareness of statistics from Conception 4 to Conception 5, as her next quote illustrates.

5. **Statistics is a way of understanding real-life using different statistical models.**

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

Melissa: (What do you find interesting or important about statistics to you?) To me personally? (Yes.) Being able to put reality into models, just that we are not really thinking it’s happening, we know it’s happening. (Explain.) We see things happening everyday and learn by it, even things like the weather or native plants, and we can see it is happening; but, see, for me I don’t like believing something is happening until I see it. I like proof, and for me the mathematics or statistics behind it is the proof.

Danny: I think there is so much statistics that are in the wrong hands and is incorrect. Like you can read things in the paper. I mean we have had things at work where you read it and you think "there is no way you can make that assumption from 600 surveys you have sent out, 200 people responded, therefore we can’t say this." And you think "you can’t say anything from that." If so many people haven’t responded, what sort of opinions is it based on? But I suppose that is getting away from "what is statistics!" Probably something a bit stronger than a tool. I think it is a means of understanding relationships between data and information, making it cohesive.

Joe: The theory is important, it lays the foundation for the actual real world problems. You are not going to make money in the real world as a stats consultant or as an analyst knowing the theory behind the work. Whereas if you can solve a business’s problems, that is more important I feel. (So can you define for me what you think practical is?) Practical in that sense would be, here is a set of data, analyse it and come to a conclusion. In regression obviously it is to find a model that best describes the situation. Regression is a science which allows you to model a situation, and at the end it can be used for a few things like forecasting the future, predicting the future, or it could be used to … to try to predict. (Thinking of your whole study of statistics so far, what’s been the most interesting thing you’ve discovered?) In statistics? The way that the actual techniques that we use, the way they model a situation so accurately. That’s the most important. To look back at something and to say: “this is what I’ve got, hey, that really works!” That’s important and that’s the most interesting.

Natasha: What is statistics? (long gap) Being able to verify any thought you might have on your
data and being able to verify and back it up with some sort of mathematical model behind it to get some kind of conclusion out of it.

Chris: Well, out of all the different mathematics subjects that I have been exposed to, I find statistics the most applicable because the thing is you are dealing with real life situations. ... So, basically, I like it because it is more applicable and the subject is more tangible and more easy to grasp, and because it is more applicable there is more incentive for you to learn it. Well, I enjoy statistics in general. I think it's very interesting. What I get personally out of it ..., well I basically just enjoy the subject. Also, it helps my thinking in terms of structuring models, because statistics, regression analysis, is one subject I've done that helps us create models and look at modifying models, like, statistical models, but I haven’t really done something like this in my other subjects. So it also helps me, it trains my thinking to be able to come up with a good solution when looking at a whole model and looking at all those different variables. Oh, well, basically, you have a set of data and you try to make some sort of inferences on a population from some sample you have collected. ... So basically you can use it, it helps you to ... try and find solutions to problems, basically, and that is useful and important, because it helps in all of research and work, and things like that.

The final conception is qualitatively different from all the previous conceptions, as it focuses on meaningful relations between the data, the model and students’ own experience and understanding of life. It represents another major qualitative jump in students’ conceptions of statistics.

A focus on meaning

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. However, this is only one aspect of the statistical analysis: beyond this, students use statistical methods to develop their own thinking, to create new interpretations of data and life. These students actively relate their statistical understanding to the data, the interpretive models, to wider aspects of reality and to their own creative and critical thinking. This conception is quite unlike the other conceptions as it focuses on the importance of meaning. As this is the most inclusive, integrated and expansive conception, students expressing this view may use any or all of the characteristics of the previous conceptions, if their perception of the situation demands it.

Paul: *I want to achieve understanding of what statistics actually means and how you interpret statistics in the real world and what is the value of statistics. I mean, when someone says here is the data and now give me the statistics. So there is know-how, even though you might know how to interpret it, but you don’t know how you derived it. So I just feel uncomfortable when I am looking at a piece of data or some sort of statistic and I don’t know, I don’t understand how they derived from. All I want to achieve is how to get in depth understanding of what statistics is. What I try to do is I try to apply the academic theory or concept into work and see if it is helpful or if it makes sense at work too, otherwise you have to make a lot of assumptions before you can say that. So then I consult the lecturer and say is that ok or would that be right if I apply it to my work like that.*

Jessica: *(What do you find interesting or important in statistics for you?)* It’s pretty relevant in lots of things. Like, they might compare cultures or something like that, and just the statistics involved in ..., for example, in our exam there was a question about drugs, and it’s just interesting just what they get out of statistics and how they analyse people and things and life in general from statistics. I find that interesting.
Helen: You can act as a detective by just using numbers and that is what I find so interesting. There are so many different conclusions that you can draw from the study of statistics, which is what I like about it. Particularly what I get out of it is that I am seeing more and more everyday with all these huge social changes that we have had, not only nationally but internationally. Statistics is quite important in that it allows us to look at these changes, do the numbers and perhaps look at implementing any changes that may need to be made. Counseling every single person, every single living being on this earth then simply gathering the data, gathering our sample data which we need, studying that, analysing that, looking at any particular pattern which may be recurring in this data. It allows us to make more or less some generalisation about what is happening in the current world and that allows us to see what is actually happening, the way people are going, the direction in which they are headed and that to me is what I find important about statistics.

Anne: (What do you find personally motivating or interesting about statistics?) It makes me think. It really challenges my mind because this way I am not relying on textbooks, I am relying on my own interpretation of the data and things like that, and I think that because when you going to work you don’t need to do these small calculations, you need to be more analytical, and I find that I like enjoying challenging myself to think beyond what is presented in front of me, and it is more relevant into the work place rather than just text and just memorising things. I am learning now direct applications of finance. I understand that finance is not just, there is a protocol or there is a type of procedure where you just do business, it is a whole art, like, it is like when assets are priced, it is not just like somebody goes "I think this is a good number" and the other person just bargains, it is a whole model, you can actually build a model using statistics and probability and then it makes it more interesting for me to see that I am actually creating something using statistics to create something. I am not just doing like clerical work, like you know how accounting people they just write the numbers in, I am not saying that is boring or anything I am saying it is much more challenging and creative and I think that is what attracts me to that field because I have a very creative side and I like thinking harder and beyond what is given to me.

It is important to note that as the categories are hierarchical, individuals who experience statistics at the most inclusive level are able to - and do - appreciate and use characteristics of the less inclusive levels. For instance, our illustrative quotes include a statement from Helen as part of the description of Conception 1 (statistics is individual numerical activities) as well as for Conception 6 (statistics is an inclusive tool used to make sense of the world and develop personal meanings). These quotes came from different places in Helen’s transcript and show clearly how she is aware of the whole range of conceptions. In particular, the quote in Conception 1 illustrates a limiting view of statistics that she acquired in secondary school. However, it is much harder for an individual who usually experiences the narrower conceptions to broaden their view to the more inclusive conceptions (Reid 1997b). Kim, Pat, Lee and Julie (as well as some other students whose words were not used to illustrate Conception 1) only described their understanding of statistics at the most limited level, and didn’t seem able to view statistics in terms of the more expansive conceptions.

Table 1 displays the outcome space, summarising the approach and focus of each conceptual category. There are two important ideas to note. Firstly, as the categories are inclusive, those students who report the more expansive levels will also have a wider range of approaches to statistics, while those that report the more limited levels do not have access to the same range. Secondly, one can see from the diagram that there are three main qualitative differences between categories defined by the difference of approach and focus. Thus, when the focus is on techniques (Conceptions 1, 2 and 3) then the related approach is to gather statistical methods, when the focus is on data (Conceptions 4 and 5) then the related approach is applying techniques to the data, and when the focus is on meaning (Conception 6) then the related approach involves creating models and explanations that help to illuminate reality.
The diagram provides a graphic means of understanding this relation. Those students who identify only the least inclusive conceptions are only able to use a single approach. At the other extreme, students who identify the most inclusive conception will maintain their focus on statistics but can use the whole range of approaches to support their learning. We have always known that students in our classes have understood statistics, learning statistics and working as a statistician in many different ways. The results of the present analysis have described these differences and now give us information that can be used to develop learning environments that can help students broaden their global understanding of statistics as well as their approach to the subject.

These major qualitative differences in students’ understanding of a specific discipline have been observed in other contexts. The following section describes our investigations of students’ notions of work in a broad range of areas, and how they may be related to their understanding of their discipline within an institution. Finally, we draw some implications for the teaching and learning of statistics in higher education institutions.

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**Table 1.** The outcome space for students’ conceptions of statistics.

| Approach | Focus        | Professional Entity       |
|----------|--------------|---------------------------|
|          | Technique    |                           |
|          | Data         |                           |
|          | Meaning      |                           |
| Gathering| Conception 1 | Extrinsic Technical       |
|          | Conception 2 |                           |
|          | Conception 3 |                           |
| Applying | Conception 4 | Extrinsic Meaning         |
|          | Conception 5 |                           |
| Creating | Conception 6 | Intrinsic Meaning         |

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**4. The Professional Entity**

Research in other academic disciplines suggests that there is a strong relation between students’ (and teachers’!) perception of work and their conceptions of their discipline and learning within that discipline. Reid (1997a) first articulated this relation in her work with musicians and their students, describing the "Music Entity," a tripartite hierarchy of conceptions of working as a musician. Reid (1999) wrote that “The identification of the Music Entity as an experience of the professional world that is related to teaching and learning suggests that the constitution of categories of description of phenomena in future studies needs to be reconsidered. This reconsideration would reflect the relation of the group’s experience of the professional world and the relation an awareness of this world may have with teaching and learning in associated disciplines.” The significance of the experienced world as expressed through the Music Entity is that conceptions of teaching and learning exist within a rich and multi-dimensional framework. Further research in theology (Morgan 1999), design (Davies and Reid 2001) and environmental studies (Loughland, Reid, and Petocz 2002) lends support to the idea that the Music Entity is a manifestation of a
more general phenomenon that we have chosen to call the "Professional Entity," as the same three qualitatively different ways of understanding the nature of work seem to be manifest in a broad variety of fields.

The abstract notion of the "Professional Entity" is a way of thinking about students’ (and teachers’) understanding of professional work. It consists of three different levels which may be described as Extrinsic Technical, Extrinsic Meaning and Intrinsic Meaning: they are shown for the field of statistics on Table 1. 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. In music this was manifested as a group of instrumental techniques and musical elements, in design as a "palette" of spatial and visual techniques, in theology as Biblical commands and custom, and in environmental studies as knowledge about specific ecosystems. In the field of statistics, the Extrinsic Technical level focuses on the gathering and application of mathematical or statistical techniques (Conceptions 1, 2 and 3). A characteristic of this limiting view is that professional work simply exists, and is experienced as being quite external to the individual.

The Extrinsic Meaning level describes a perception that professional work is about developing the meaning inherent in discipline objects. In this sense, musicians and their students indicate that musical manuscript is full of historical and stylistic meaning that needs to be discovered and accurately reproduced, designers look at the inherent meaning found in the created artifact, theologians discuss the overall meaning of religious books and environmental scientists focus on a recognition of eco-centrism. In statistics, the Extrinsic Meaning manifests itself as statisticians explore and examine the meaning found in a set of data (Conceptions 4 and 5).

The third and broadest level of the Professional Entity is the Intrinsic Meaning level. In this view, people perceive that their professional work is related to their own personal and professional being. This means that musicians see the instrument, the manuscript and the performance as a means of communicating their own story or feeling to an audience, designers communicate personal meaning through a visual artifact, theologians integrate Biblical truth with their own interpretations to assist other members of their community, while environmental scientists understand that there is a symbiotic relation between self as part of humankind and the world environment that results in a mutually sustainable existence. The Intrinsic Meaning level is shown when statisticians create and develop their view of the world by testing their understanding of the world with statistical evidence in the form of data (Conception 6).

Understanding the nature of the Professional Entity in statistics is critical. The research studies cited suggest that there is a very close relation between the way that teachers and students perceive the profession and what they then think is critical to either teach or learn. An awareness of the Professional Entity can be important when materials for learning are being developed. Reid and Petocz (2001b) have described the relation between the Professional Entity in the context of music and the development of the multi-media package Creating Ensemble (Blom et al. 1998). In that package, the three levels of the Entity were explored through suggestions for student activity and the visual and audio representation of music. In this way, students were encouraged to examine their own beliefs about the nature of professional music-making and were made aware of the more integrated Intrinsic Meaning category. An awareness and exploration of the Professional Entity in the context of statistics provide a similar basis for the development of learning materials and curriculum in statistics to that of music. The approach is being used in the preparation of a text, Reading Statistics (see Wood and Petocz 2002), which asks students to explore published articles involving applications of statistics in a range of areas supported by questions and activities.

If we return to the suggestions of Weinberg and Abramowitz (2000) and Batanero (2001), we can see that recognition of the ways that students understand statistics, and hence the development of effective
learning environments, is aided by the identification of the phenomenographic categories and their alliance with the Professional Entity.

5. Implications for Learning and Teaching Statistics

Above all, the research reported in this paper points out the wide range of conceptions that students of statistics have of their subject. It is important to note that these students were not taking statistics as a "servicing" subject - they were all enrolled for degrees in mathematical sciences, and they would all expect to use statistics professionally in their future careers. In our context, although the sample was too small to draw any conclusions about the prevalence of the individual categories (nor was this the aim), it is notable that students in first year and in third year described the full range of categories. This indicates that the categories are not developmental but simply a feature of students’ experience. We cannot assume that students in third year will naturally have more expansive views about their discipline or that all students in first year have limiting understandings of statistics (although we have heard arguments for this at many faculty meetings!). The first, and most obvious, implication for teaching and learning statistics is to recognise that this range of variation exists, seemingly at all levels of university study. As statistics educators, we need to cater for this variation in terms of our pedagogical methods and materials.

There are important implications from this finding for curriculum development. There is evidence in the transcripts to suggest that students who are aware of the more inclusive levels can use the approaches that relate to the less inclusive conceptions if their perception of the situation demands it. Students’ perceptions of their learning context are important factors in the approach that they take to their learning. For instance, a class environment focusing on the Extrinsic Technical level - emphasising the learning of correct definitions and techniques, the meticulous completion of assigned questions, and concluding with a "rigorous" examination that rewards rote learning - may encourage students to focus simply on the acquisition of statistical techniques (Conceptions 1, 2 and 3). Thus, those students who are aware of broader conceptions will be encouraged to work using the narrower and more limited conceptions. There is evidence in the transcripts that students who have a broader understanding of statistics can carry out their academic work using a narrower view (illustrated by the quotes from Emma in Conceptions 3 and 4).

In contrast, we could set up learning environments that encourage students to develop the broader conceptions of statistics (Petocz and Reid 2002b). The importance of developing learning environments that encourage students to use the broader conceptions - to look for meaning in the data and relate this meaning to their own personal situations - cannot be understated. As an example, focusing on (and assessing) the ways in which students meaningfully interpret data and provide advice to "clients" (other students) as a result of their analysis will have the effect of enabling students with less inclusive conceptions of statistics to experience alternate ways of "being a statistician." There is evidence in the transcripts that students can move from limiting conceptions to the more expansive ones, most dramatically in Helen’s quotes in Conceptions 1 and 6. Reid (1999, p. 146) gives another example (in the context of learning music):

Jane: Well, I think I would never have picked things up if he [her teacher] hadn’t pointed them out. It’s not like he’s forcing some kind of teaching onto me: it’s just that he says things which I just hadn’t thought about or I’d taken for granted, and I think about them and it helps me to consciously focus on using those things, and it changes the way I learn.

It is not only students of statistics who have different conceptions of statistics. Even professional statisticians often debate the nature of their subject. For example, Fisher (2001, p. 3) asks rhetorically, “Is there any profession whose practitioners are so afflicted with self-doubt that questions such as 'What is statistics?' or 'Whither statistics?' are frequently debated, with little evidence of significant advancement
"let alone resolution?" The answer is in the negative, and the four short papers that follow illustrate four quite different views of the nature of statistics (Cleveland 2001; Friedman 2001; Nicholls 2001; Smith 2001). McLean (2000) puts forward a view of statistics commonly held by some educators when he writes “Statistics is commonly taught as a set of techniques to aid in decision making.” The varied messages about statistics that students get from their teachers are another important aspect of their learning environment. Some indicate that statistics is a rather hard, but necessary subject for mathematicians, whilst others indicate that statistics is an exciting career option that enables one to work with a range of people on "real" problems. Students’ formal and informal experiences of statistics result in them forming the conceptions described in this study.

We plan future research to effectively map the differences in the ways that professional statisticians (especially academic statisticians) understand statistics and teach and learn statistics. Reid (1997b) has shown that the teacher’s conception of the nature of music is an important determinant of a student’s approach to learning music. A teacher with a broader conception of the subject encourages students to develop these broader conceptions: however, a teacher with a more limiting conception tends to provoke students into a more limiting approach, even those students who are aware of broader conceptions. Given the parallels between music and other subject areas including statistics in terms of the identification of the Professional Entity, this important finding is likely to be true in statistics as well.

Ramsden (1992) points out the difference between teaching that encourages "deep approaches to learning" and teaching that encourages "surface approaches to learning." Here, we are focusing on pedagogy that encourages students to develop more expansive rather than limiting conceptions of their subject. The following two quotes from our interviews illustrate the difference:

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.

The activities and assessment that are used for learning need to place less emphasis on the acquisition of statistical techniques (although this is an important component). Rather, they should emphasise the meaningfulness of what is uncovered using statistics, both in terms of the specific context and in terms of students’ own lives. delMas et al. (1999) suggest that interventions in the learning environment that focus on individual statistical topics are unlikely to “guarantee conceptual change." Planning a statistics course should consider much more than the list of "topics to be covered" or even the approach to these topics (Roiter and Petocz 1996). It is also important to help students appreciate the importance of statistics outside the educational institution, and to encourage them to develop an appreciation of their relationship with the subject. Another idea that could be explored is to actually discuss with students the range of conceptions of statistics and of learning in statistics as part of their study of the subject. Given that this is commonly and successfully done in professional development courses (such as the Graduate Certificate in Educational Studies at Macquarie University) with lecturers, it is likely that university students would also benefit from such an exploration. Indeed, some professional statisticians (such as Cleveland 2001) recommend that some discussion of pedagogy should form part of the curriculum for undergraduate statistics courses.

In summary, then, curriculum needs to accommodate variation in student conceptions, both because this variation exists and in order to help students broaden their awareness of statistics. It will also be
important to explore the nature of statistical work and to highlight statistics as a profession to demonstrate the applicability of students’ studies to their future work and professional roles. In order to help students to consider the broadest and most inclusive conceptions of statistics, the curriculum also needs to encourage them to be aware of their perception of their own place in the world, and to develop a critical appraisal of how statistics can help them in this endeavour.

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