UNDERSTANDING STUDENTS' EXPERIENCES OF STATISTICS IN A SERVICE COURSE

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SUMMARY

In this paper we explore issues surrounding university students' experiences of statistics drawing on data related to learning statistics as a compulsory component of psychology. Over 250 students completed a written survey which included questions on their attitudes to learning statistics and their conceptions of statistics. Results indicated that most students were studying statistics unwillingly. A minority of students acknowledged that statistics was necessary for psychology, but statistics was seen by many as boring or difficult. Students' conceptions of statistics were analysed from a perspective developed from phenomenography (Marton & Booth, 1997). The aim of phenomenographic research is to describe the qualitative variation in the ways people experience or conceptualise a phenomenon — in this case students' interpretations of the topic statistics. The conceptions fell into five categories of description including: statistics as decontextualised processes and algorithms, statistics as a tool for professional life and statistics as a way to self-development and enhanced perspectives on our world. Excerpts from interviews with selected students indicate the diversity of experiences in learning statistics. The perceptions of two teachers flesh out the learning and teaching environment. The findings raise challenges for supporting the learning of "occasional users" (Nicholls, 2001) of statistics in higher education.

Keywords: Statistics education research; Service course; Affect, Conceptions; Phenomenography; Activity theory

1. INTRODUCTION AND BACKGROUND

This paper brings to the foreground important, and often invisible, issues surrounding statistics service courses. These are highlighted through a case study on university students' learning of statistics as a compulsory component of psychology. We examine empirical data on the students' feelings about learning statistics and the students' interpretations of the topic, statistics, they were studying. The data alert us to look beyond the statistics curriculum to the broader context of learning, including affective dimensions and students' interpretations of the subject, statistics.

In recent years there has been a much needed and well-focused series of publications researching the teaching of undergraduate or introductory statistics courses and making recommendations for the reform of these courses (Hogg, 1999; Garfield, Hogg, Schau, & Whittinghill, 2002; Moore 2001). Hogg (1999) suggests using continuous quality improvement to improve undergraduate programs and statistics courses. Garfield et al. (2002) propose that desired outcomes of introductory statistics courses include not only statistical learning and understanding, but also students' willingness to persist in their learning and application of skills, and positive attitudes and beliefs about statistics. Moore (2001) discusses the need for realism and inter-disciplinary cooperation in formulating statistics programs for undergraduates.

In the literature on reform of statistics courses, research on affective reactions and attitudes towards statistics has been, for the most part, neglected. Gal & Ginsburg (1994) found that "the body of research on students' attitudes, beliefs, and affect related directly to statistics education is very

small and problematic". Further, the data relied on paper-and-pencil, Likert-type scales, in which items included statements using the word 'statistics'. Hence understanding how students interpret the word 'statistics' is critical to interpreting the results of these attitude surveys. Gal & Ginsburg (1994) conclude that further attention by both statistics educators and researchers should be focused on beliefs about statistics, attitudes to learning it, and expectations that students bring into statistics classrooms or develop while studying statistics. These are challenges and opportunities for statistics education today.

The primary focus of the literature in undergraduate statistics education is on introductory statistics courses offered by mathematics or statistics departments. Published data on service courses in statistics, taught by other departments, are harder to access. Indeed Garfield et al. (2002) comment that teachers of statistics in the biological or social sciences are harder to reach and support. The literature provides valuable examples of course design, teaching approaches, curriculum outlines and assessment strategies in statistics courses in diverse areas such as chemistry and business (Zetterqvist, 1997; Yilmaz, 1996). These focus on 'real world' applications of statistics for non-specialists. However there are few data on affect and its impact on learning statistics as a service course.

The challenges facing statistics education at the tertiary level are particularly poignant in service courses for "occasional users" (Nicholls, 2001), such as for social sciences. Issues include: the training of and background of instructors; communication within and between departments; cramming of curriculum into decreasing time slots, as competition for student time increases; and support of statistics teachers in university departments where colleagues may include few, if any, statisticians. These issues also impact on curriculum reform in service courses in statistics. For example, the well documented neglect of variation in statistics courses is exacerbated in service courses (see Meletiou, 2002, for a review of the literature on variation and its neglect). Further, the availability of powerful and easy to use statistical software can enable "occasional users" of statistics to "undertake technically difficult analyses without the formal theoretical background to fully understand how the results are being derived" (Nicholls, 2001, p.13). Green (2002) notes that conference participation by instructors of statistics is essential, not only so that statistics educators find out what is going on elsewhere, but also for them to make contact with others in the field of statistics education. One concern for professional bodies in statistics education is how to encourage teachers of statistics in service courses to participate in statistics education conferences or sessions in statistics education — when their research interests may lie in other disciplines or fields — and there may not be institutional support for participation in statistics education conferences.

The challenges facing statistics education in universities and other tertiary institutions are embedded in the challenges to higher education in general. A recent review of higher education in Australia identifies factors transforming the context of higher education (Department of Education, Science and Training, 2002). These factors include a shift from an elite education system to a mass education system with increasing diversity of students, changing patterns of enrolment, such as increased part time study, impact of information and communication technologies, and expectations of graduates held by employers. Ongoing transformations are altering the focus and very nature of higher education. According to the Department of Education, Science and Training (2002, p. 2):

> There is an ongoing debate over the 'what' of higher education. This is exemplified by the tension between whether higher education should provide students with a liberal, general education, with a focus on learning for its own sake, or a professionally focused, specialist preparation for the workforce.

Moreover, in the Australian higher education system, there is an increased dependence of universities on private funding, decreased resources, more emphasis on accountability, and substantial changes in the ratio between students and teaching staff - a 38.6% rise in this ratio the last eight years (Kent, 2002).

Systemic changes such as these are transforming higher education in many countries and affect statistics courses at universities. They translate into practical terms, defining the resources available to university teachers and impacting on the ways teaching statistics is organised or constrained. For example, a university teacher of statistics interviewed for this study (section 4.6) perceived that multiple-choice examinations are an undesirable method of assessment but "essential for financial

reasons". Engeström (1999) pointed out that if practitioners are able to identify and analyse contradictions and tensions in the system surrounding and shaping their activities they may be able to focus on resolving the contradictions and reorganising the activity, "instead of being victimised by changes that roll over them as if forces of a natural catastrophe" (Engeström, 1999 p. 68). To do this the tensions must be made visible - as when a practice is shared and common it becomes invisible.

The aim of this paper is to provide a basis for reflection on issues and challenges that could arise in service courses of statistics. The paper is organised in layers. The outer layer is the broader environment for statistics education at university - the political, philosophical and pragmatic issues that shape the experiences of teachers and students in statistics service courses. These were briefly outlined above and will be contextualised in an empirical study. The next section describes the theoretical and methodological lenses through which I interpret a case study on students' orientations to learning statistics as a unit of study of psychology. Activity theory provides a framework for linking students' orientations to learning statistics to the learning environment surrounding and shaping these orientations. In tandem with the relational view of an activity theory framework, I use a phenomenographic approach to exploring students' interpretations of statistics in the context of a psychology course. The core of the paper is an empirical study conducted at a major, metropolitan, Australian university. I report on psychology students' written responses to survey questions on their feelings about learning statistics and how they interpret the subject statistics. Excerpts from interviews with students are reported to supplement the written survey responses and interviews with two teachers of psychology statistics add to the context for the students' responses and flesh out the teaching and learning issues outlined in this introductory section. The data reported in this paper are aspects of my PhD thesis (Gordon, 1998).

The position of the researcher is important in any investigation. My interest in psychology students learning statistics arises from teaching at a Mathematics Learning Centre in a major Australian university. The Centre provides ongoing support for students of my university who seek assistance with basic level mathematics and statistics courses. I take responsibility for and joy in teaching the psychology students at the Centre who are studying statistics. As a teacher in the Mathematics Learning Centre I am an outsider to the psychology statistics course in that I have no input into the curriculum, teaching strategies or assessment of this course. My practice involves supporting the statistics learning of psychology students at the Centre and researching their learning (Gordon, 1995). This study aims to give the students a voice — how they felt about learning statistics and what their conceptions or interpretations of statistics were. Hence this paper is an attempt to balance personal experiences teaching statistics in the Centre and researching students' learning with issues in the broader context of statistics education.

2. THEORETICAL FRAMEWORK

Activity theory, based on the powerful ideas of Vygotsky and Leont'ev (for example, Leont'ev, 1981; Vygotsky, 1978), can be an effective tool for understanding learning. This theory explains that people actively develop knowledge on the basis of life experiences that are rooted in the ongoing practical and communal life by which societies organise and reorganise themselves. The activity of learning is a process in which people grapple with new information - to make it meaningful, to solve problems and to adapt to new conditions.

The importance of the theoretical framework to this investigation is twofold. Firstly, it centres our attention on students' actions, including mental actions, and their goals - what students do and why they so act. Secondly, it brings the context of learning to the foreground. When students learn statistics they interpret it within their own frameworks. The ways students learn statistics reflect their personal stories, their experiences, needs and goals. Moreover, students' activities are organised within and shaped by the histories and cultures of their institutions, as well as the social factors prevailing in their statistics classes. It is by looking at the context in which students learn statistics that we can make sense of their actions. How students think and act depends on how they position themselves - what the students believe to be strategic in the circumstances.

Activity theory emphasises the developmental nature of human actions and thinking. Activities progress and transform over time. Varela, Thompson and Rosch (1991, p. 205) describe cognitive capacities as: "paths that exist only as they are laid down in walking". Their metaphor beautifully illustrates the inseparability of personal meaning and setting - the co-emergence of thought and action - knowing as doing. An implication of the developmental approach is to view students' interpretations of statistics as having developed through their experiences and schooling over a long period. For example, experiences of learning mathematics at school may impact on learning statistics at university. This development is also ongoing. The results of this study are a snapshot - we can only capture a moment in an ongoing progression in the students' thinking.

In sharp contrast to psychological theories in which cognitive processes are viewed as separate from the emotional domain, activity theory emphasises the inseparability of students' feelings from their thinking. Vygotsky (1962, p. 150) describes this inseparability of intellectual processes and affective elements as follows:

> Thought itself is engendered by motivation, i.e. by our desires and needs, our interests and emotions. Behind every thought there is an affective-volitional tendency, which holds the answer to the last 'why' in the analysis of thinking. A true and full understanding of another's thought is possible only when we understand its affective-volitional basis.

Affective elements operate as invisible dimensions of student learning, neither acknowledged nor valued in statistics education. Lerman (1996) argues that the valuing of decontextualised, intellectual processes, divorced from personal elements, is expressive of oppressive discourse. It is this privileging of abstract thought, such as academic mathematics, that is disempowering for some students. Sierpinska & Lerman (1996) refer to the vested interest mathematicians have in maintaining the status of mathematics in society. This idea was passionately expressed by a statistics student. This student identified statistics with mathematics. She wrote in her survey (Gordon, 1998, p.18):

> Maths is an exercise in agony, because the people who teach it make one feel as though maths belongs in a higher plane of evolution. Even though the number system is for everyone, and the concepts are there for everyone, the feeling (especially if you are doing pass options) that you do not deserve to know anything runs rampant.

Leont'ev (1978) makes a useful distinction between meaning as 'cultural' or 'personal'. Cultural meanings are connected with the reality of the outside world, the life of society. Personal sense, on the other hand, is connected with the reality of the person's own life, motives and goals — what is significant for the individual. Society endorses statistical information as scientific and useful but to some students statistics is neither relevant nor important. Hence sometimes there is a mismatch between societal and personal meaning. It is affect that determines the fit — how cultural meanings are translated into personal sense. What is culturally endorsed, for example, achieving high grades in mathematics, may not translate into personal motivation if the student hates mathematics or is anxious and apprehensive about learning it.

2.1 BACKGROUND TO PHENOMENOGRAPHY AS A RESEARCH TOOL

The approach taken in this study to analyse students' conceptions of statistics is based on phenomenography. Phenomenography is a well-established, qualitative, research tool in education research that seeks to uncover participants' own conceptions or experiences of a phenomenon in varied contexts (Marton, 1986; Marton & Booth, 1997). The results of phenomenographic analysis are categories of description that capture the essence of each conception. That is, the categories reflect critical differences in the participants' expressions of their conceptions. For example, my colleagues and I found phenomenographic methods useful to explore the qualitatively different ways in which students experience learning mathematics (Crawford, Gordon, Nicholas & Prosser, 1994). In that study conceptions of mathematics were found to divide broadly into categories expressing fragmented conceptions of mathematics, such as mathematics being about numbers, rules and formulae, and categories expressing cohesive conceptions, where mathematics was seen as being about a complex logical system providing insights about the world. Reid and Petocz (2002) investigated the conceptions of statistics held by students enrolled for degrees in mathematical sciences. They

described six qualitatively different conceptions of statistics ranging from fragmented to inclusive views. The six conceptions were grouped in terms of the focus of the conception, namely a focus on techniques, on data or on meaning. In this paper the categories describe the qualitative variation in students' conceptions or interpretations of the topic statistics, as indicated by their responses to questions which were part of a written survey.

The set of categories that is the outcome of a phenomenographic investigation represents an awareness of the phenomenon which is a collective rather than individual. Phenomenographic analysis starts with accounts of individual experiences from which categories of description are developed. In developing these collective categories individual idiosyncrasies are ignored. Individuals are seen as "bearers of fragments" (Marton & Booth, 1997, p.114) of each conception category so that any one person's expression of a conception may not fully sum up the category. A strength of phenomenographic analysis is that the categories of description are developed from the data and are not preconceived. The researchers try to step back from their own perceptions or "bracket them" (Ashworth & Lucas, 2000) and attempt to see the phenomenon, in this instance the experience of learning statistics, through the eyes of the students.

A phenomenographic perspective is relational in the sense that a person's experience or awareness of the phenomenon constitutes an internal relationship between the person and the phenomenon (Marton, 1988). Svensson (1994, p. 12) argues that underpinning the phenomenographic "specialisation" is an assumption that knowledge is fundamentally a "question of meaning in a social and cultural context". Marton & Booth (1997) emphasise that conceptions or experiences are neither psychological nor physical but are descriptions of the internal relationship between persons and phenomena; "an experience is of its essence nondualistic" (Marton & Booth, 1997, p. 122). Hence phenomenography emphasises the relatedness of individuals, the context and the subject matter, statistics.

Any research tool develops as it is applied and in this paper the phenomenographic approach is developed in accordance with the activity theory framing the investigation. Students' conceptions of statistics are interpreted as understandings of statistics experienced by the students while studying statistics. That is, conceptions, rather than being purely mental images, in the head, are accompanied by and inseparable from emotions, goals and actions taken to study statistics.

3. METHODOLOGY

In this paper we explore students' written responses to part of a survey. These data are supplemented by excerpts from audio-taped interviews with selected students and two university teachers. The participating students were studying statistics as a compulsory component of second year psychology at a major and traditional metropolitan university in Australia. The survey forms were handed out to 279 students and completed in writing by these students during 20 minutes of a statistics lecture, near the end of the first semester, with the co-operation of the lecturer concerned. The theoretical position described above suggests that learning will be shaped by students' perceptions and the survey was designed to elicit students' own views and perceptions on learning statistics. The survey was completed by all students attending the statistics lecture on the given day and it is a matter of conjecture whether the students present at the statistics lecture differed from the absentees concerning the study of statistics. Hence the sample may not be representative of the cohort of second year psychology students.

The survey included open-ended questions on students' willingness to study statistics and their interpretations of the subject, statistics, which will be analysed in this paper, as well as a questionnaire on approaches to learning statistics (discussed elsewhere, see Gordon, 1999). Later in the year seven students were selected for interviews based on the ongoing analysis and categorisation of survey responses. These students were selected because their diverse survey responses typified, as far as possible, the different analytic categories that had emerged by that time. I also ensured a range of values on variables such as age, gender and background in mathematics for the students interviewed. Two teachers of the psychology statistics course were interviewed to shed some light on the course from the teaching perspective.

The open-ended survey questions are shown below. In what follows we focus mainly on students' responses to Question 1 and Question 3, although responses to Question 2 were taken into account in the analysis as will be explained in section 3.1.

Question 1. Would you study statistics if it were not a requirement of your psychology course?

Please give reasons for your answer.

Question 2. Think about the statistics you've done so far this year.

a) How do you go about learning it?

b) What are you trying to achieve?

Question 3. What in your opinion is this statistics course about?

Please explain as fully as possible.

Analyses of students' responses to Question 1 above are presented in sections 4.1 and 4.2. Section 4.3 describes students' performances in assessments. The categories of conception that emerged from the phenomenographic analysis are discussed in section 4.4 with quoted excerpts from the surveys that illustrate the categories as best possible. Interview data from students, which flesh out the written survey responses, are reported in section 4.5 and excerpts from interviews with two teachers of the course are provided in section 4.6.

Student learning is set within a particular context in space and time. At the time of data collection and analysis the statistics course consisted of one lecture and one tutorial per week, each an hour long, and the course continued for two semesters (that is, one academic year). The course was taught in the traditional lecture-tutorial format with assessments being primarily open-book quizzes, assignments and examinations. Students did not have access to computer workshops but were presented with SPSS outputs for analysis and interpretation.

Diversity is a hallmark of student groups at university and the participants of the study were diverse in educational background and experience, expertise in mathematics, age and other demographic variables and course of study undertaken. The participants were enrolled for various degree courses with the majority pursuing Bachelor of Arts degrees (183 students, 66%). The bulk of the rest were studying degrees in Science (48 students, 17%), Economics (19 students, 7%) or Education (15 students, 5%). Most of the students (184 students, 66%) were either 19 years old (133 students, 48%) or 20 years old (51 students, 18%) though a sizeable minority (46 students, 16.5%) was at least 25 years in age. About three quarters of the students were female. The prior level of mathematics studied by the surveyed students was higher than is often assumed for psychology students. Fifty eight percent (163 students) had studied mathematics at school to a level which included Calculus and a further 68 students, almost one quarter of those surveyed, had studied mathematics at university for at least one year.

All the participants had studied a short, five-week, introductory course in statistics during their first year study of psychology. Interestingly, most of the participants (57%) expressed an intention to continue studying psychology at the postgraduate level, suggesting that many were committed to studying psychology for professional reasons - to practise as psychologists. Only 7% (19) of the participants reported that they intended terminating their study of psychology after completing second year, to pursue other subjects.

3.1. ANALYSIS OF OPEN-ENDED QUESTIONS

Students' responses to the first survey question listed in the previous section were coded as "Yes" or "No" and then classified according to students' reported reasons for willingness or reluctance to study statistics.

Students' conceptions or experiences (Marton & Booth, 1997) of statistics were analysed using an approach developed from phenomenography, as outlined previously in section 2.1. The focus of this analysis was on responses to the third open-ended question. However, students' responses to Questions 1 and 2 were examined for clarification on their responses to Question 3. Consistent with the activity theory lens, the aim of the categorisation was to capture not only what the students

thought about statistics but how their mental interpretations and perceptions were expressed in action - what the students did to learn statistics and what the goals of these actions were. So students' overall responses to the three open-ended survey questions were taken into account in order to gain as comprehensive an understanding of the students' awareness of statistics as was feasible.

The method of categorising written survey responses, used in this study, was based on previous phenomenographic research conducted by colleagues and myself into students' conceptions of mathematics (Crawford et al., 1994). As for that study, the method used here involved attending to the similarities and differences in students' statements and selecting the themes or ideas that differentiated categories of conception. This involved cycles of analysis and review. In the first stages of analysis an independent researcher and I identified an initial set of categories. This was achieved by each of us independently reading and re-reading the entire set of 279 written responses and drawing up the critical statements that appeared to us to differentiate categories of description for students' conceptions of statistics. That is, the students' individual understandings or conceptions of statistics were grouped into sets of statements or categories. We then compared and discussed our interpretations and identified what Dahlgren (1984) describes as "core elements which make up the content and structure of a given category" (p. 24). In the next stages, each of us, and a third researcher, independently classified a selection of 30 survey papers in terms of the draft set of categories. The selection included responses which appeared to typify each category or, conversely, to be on the borderline between two categories. The individual classifications of the three researchers were compared, discussed and reviewed. In the ensuing discussions the categories were clarified and refined and a set of clear statements defining each category of conception was agreed upon. The different categories were delineated by the focus of each conception.

Finally, the distribution of students' responses into the categories was recorded. All the survey responses were classified into the categories by myself and one other researcher working independently. These classifications were compared and discussed in further cycles of analysis. The final distribution was a consensus between the two of us.

4. RESULTS

4.1. WILLINGNESS TO LEARN STATISTICS

In this section I report on students' responses to the first survey question:

Would you study statistics if it were not a requirement of your psychology course?

Please give reasons for your answer.

Seventy three percent of the students surveyed reported that they would not have studied statistics, if they had been given a choice. Students gave many reasons for their willingness or reluctance to study statistics. These can be broadly divided into reasons which relate to how learning statistics fits with the student's goals and interests or perceived abilities - the student's "personal" sense of what it means to learn statistics in Leont'ev's (1981) term - and reasons which have to do with the expectations of others, such as teachers or a societal view of the relevance of statistics, culturally endorsed meanings of statistics. The students' reasons as reported are accordingly grouped under the headings Personal Sense and Cultural Meaning in Table 1. Within these broad categories, Table 1 summarises the reasons that emerged most frequently from the surveys (top 6 categories). Short illustrative excerpts from students' scripts are provided to give examples of responses. These are divided into positive responses, favouring the learning of statistics, and those indicating unfavourable or negative appraisals. Many students gave multiple responses and some gave reasons that fell into more than one category, such as below.

... although I see it is necessary for psychology I find it boring and tedious.

This response was scored as positive in the category *Necessary For Psychology* and negative in the category *Interest.*

Table 1 shows, too, the number of students who gave a response in the indicated category. Each frequency is also shown as a percentage of 279 to indicate the proportion of students surveyed who

gave that response. For example, 5 students (2% of them) indicated that that they found statistics interesting, 19 students (7%) reported that statistics was generally useful in life; the categories were not mutually exclusive so, in this example, some students may have written that statistics was interesting and useful.

As can be seen, the most frequently cited reasons fell under the Personal heading and were negative, with 29% of the students reporting statistics as boring or tedious (*Interest*) and 13% of the students indicating that they disliked learning it (*Affect*). The category with the highest positive frequency was *Necessary For Psychology* with 16% of the students giving a positive response in this category. Responses in this category indicated that statistics was integral to psychology as a discipline but did not specify why this was so. Responses referring to a specified usefulness of statistics, in society or for a career, were categorised separately. Interestingly students' responses in the area of Personal Sense often referred to the students' attitudes to and experiences of learning mathematics, while responses concerned with usefulness to society or necessity for psychology (Cultural Meaning) tended to be specifically about statistics. These responses highlight the tension between statistical knowledge as culturally endorsed and the individual's personal appraisal of learning statistics.

Table 1. Reasons for willingness or reluctance to study statistics

PERSONAL SENSE

Category	Favourable Responses	Unfavourable Responses
INTEREST	5 responses (2%)	80 responses (29%)
Excerpts	*It's interesting*	*cause I generally find it dull, boring and tedious*
AFFECT	13 responses (5%)	37 responses (13%)
Excerpts	*I sort of dig numbers*	*I dislike maths intensely*
PERSONAL RELEVANCE	0 responses	21 responses (8%)
Excerpts	—	*No, it is irrelevant to my life*
CONFIDENCE	0 responses	20 responses (7%)
Excerpts	—	*Maths of any sort immediately makes me cringe*

CULTURAL MEANING

Category	Favourable Responses	Unfavourable Responses
NECESSARY FOR PSYCHOLOGY	46 responses (16%)	8 responses (3%)
Excerpts	*It is necessary in the study of psychology*	*I am not sure what relationship there is between statistics and psychology*
GENERAL USEFULNESS	19 responses (7%)	1 response (0.4%)
Excerpts	*statistics are used throughout our society i.e. newspaper reports & it is important to have an understanding of the way in which information is gathered, processed & manipulated.*	*No, it is not a practical subject*

4.2. DISTRIBUTION OF RESPONSES ACCORDING TO WILLINGNESS OR RELUCTANCE TO STUDY STATISTICS

Different reasons were given by students who responded that they would have studied statistics, even if it had not been compulsory to do so and those who stated that they would not have studied statistics, given a choice. Students reporting willingness to study statistics will be referred to as “Yes” students in what follows and those who would not have studied statistics, given a choice, will be termed “No” students. The most dramatic differences between these two groups can be seen in the bar graphs shown in Figure 1.

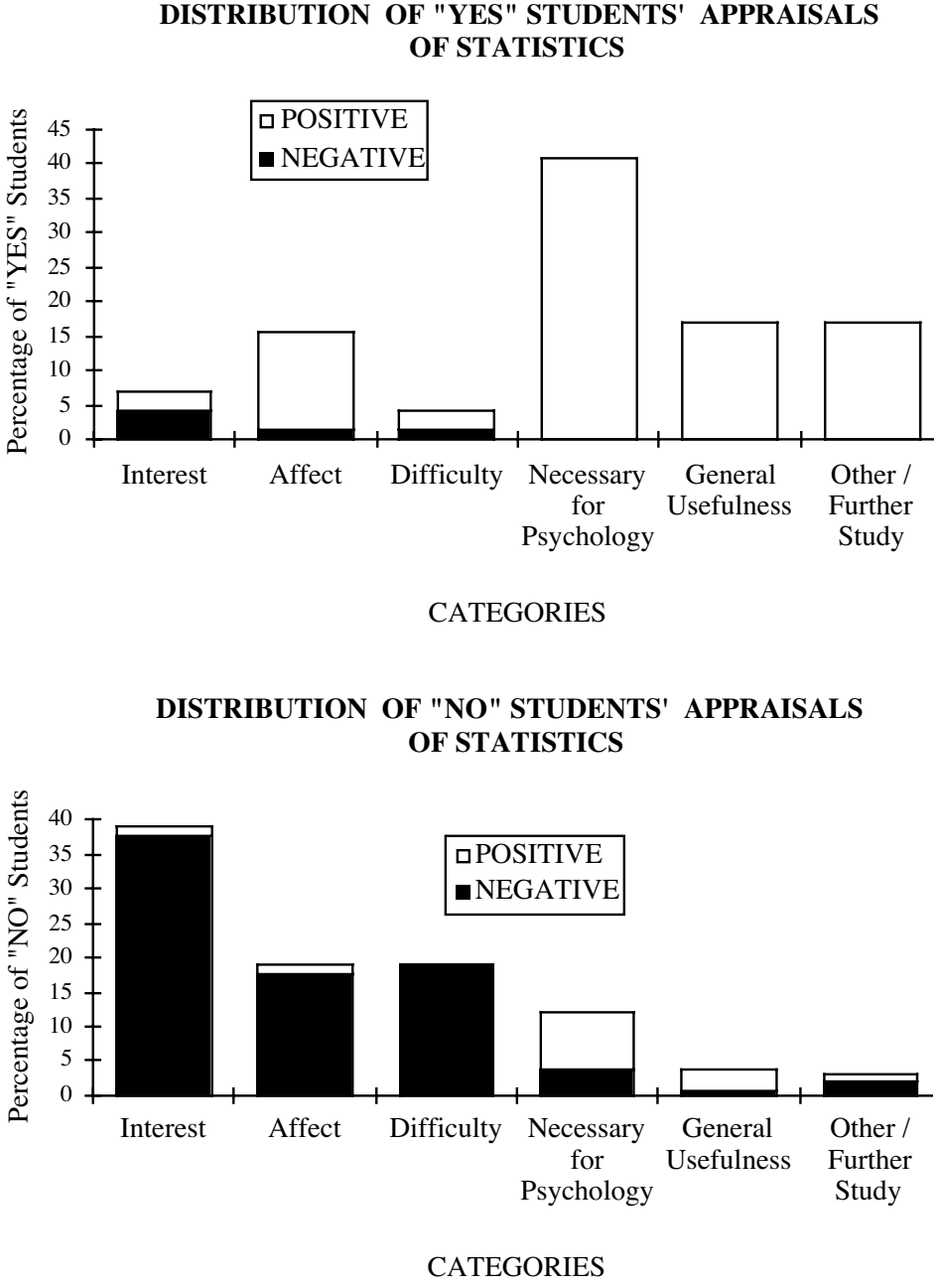

Figure 1. Reasons of “Yes” students and “No” students for studying statistics

Figure 1 compares the frequency of responses in the three most common categories for willing ("Yes") students, namely *Necessary For Psychology*, *General Usefulness* and *Other or Further Study*, with those in the three highest frequency categories for reluctant ("No") students, *Interest, Affect* and *Difficulty*. The comparison shows that, rather than reflecting opposite sides of the same coin, the reasons given by students willing to study statistics related primarily to the relevance or usefulness of statistics, while the reasons given by the reluctant majority related mainly to feelings and emotions - the "personal plane" (Leont'ev, 1978).

One interpretation of these findings is that the students who expressed positive reasons for studying statistics had "internalised" (Leont'ev, 1981) the institutionally endorsed reasons for doing so, for example the necessity of statistics to psychology as a discipline. Another possibility is that the willing students took a more mature or realistic view of the relevance of statistics to their professions or lives. However few students reported that statistics had "personal sense" (Leont'ev, 1978) for their long-term goals or self-fulfillment.

4.3. PERFORMANCE IN ASSESSMENTS

The final mark for statistics was the average of the following four components: the class mark, based on "open-book" tests or quizzes, the examination mark for semester one, and, similarly, the class mark and examination mark for semester two.

The students who expressed willingness to study statistics attained a higher average mark on the statistics tests and examinations than the reluctant learners. The mean final mark in statistics for the "Yes" students was 66% compared to 55% attained by the "No" students. This difference was not reflected in the overall performances of these two groups in psychology, excluding the statistics component (mean for "Yes students: 67%, mean for "No" students: 66%). No causal inferences should be drawn from these findings. Research on assessment procedures in statistics and student motivation shows the relationship to be complex and multi-faceted (Garfield, 1994; Hubbard, 1997; O'Connell, 2002).

4.4. CONCEPTIONS OF STATISTICS

Five categories describing students' conceptions of statistics emerged from the phenomenographic analysis. They were: *No Meaning; Processes* or algorithms; *Mastery* of statistical concepts and methods; a *Tool* for getting results in real life and *Critical Thinking*.

The categories describe the qualitative variation in the ways these students viewed statistics, as interpreted by the researchers, and each category summarises the primary focus of the expressed conception. The categories range from the narrowest and most limited interpretations of statistics to the broadest and most inclusive view of statistics. That is, the structure of the categories is a hierarchy from what Reid and Petocz (2002) call "limiting to expansive views". This means, for example, that an understanding of statistics as being about *Processes* or mechanical aspects reveals a more limited conception or experience of statistics than a focus on the application of statistics — its use as a *Tool*. Conceptions showing awareness of statistics as a tool to be used in research and professional life could include an awareness of the algorithmic, formula-based aspect of statistics, but is not limited to that aspect.

As indicated earlier, the students' responses to all three open-ended questions (presented in section 3) were taken into account to flesh out what students had written in response to Question 3. Hence it was hoped that the categories captured the students' holistic experiences of statistics including their awareness of statistics expressed in thought, emotion and action. If a student's response indicated more than one of the conception categories it was classified in the 'highest' or most expansive category. The categories, the distribution of students' responses in the categories, and brief excerpts from the surveys illustrating each category, are summarised below. The percentages given are out of 279, the number of students surveyed.

***No meaning* (4%)**

Responses in this category indicated conceptions of statistics as an imposed and irrelevant subject. For example, one response to the question "What in your opinion is this statistics course about?" was:

You tell me, I just learn.

***Processes* (24%)**

This category expressed a focus on mechanical techniques for solving statistical problems or algorithms. In this conception statistical knowledge is viewed as disconnected — for reproduction in assessments. Typical responses were:

... You don't have to understand how it works, just be able to get the right answer.

or *... computers do all the work.*

***Mastery* (33%)**

The focus of this category was on reading and understanding material as presented in class; statistics was understood as information to be accumulated and stored in order to meet the demands of assessments. For example, one student wrote:

... I am trying to achieve a basic understanding of the material & concepts & an ability to work out the problems. This will hopefully lead to a good result at the end of the year.

***Tool* (25%)**

This category indicated a focus on statistics as a useful tool. Some students indicated statistics as personally useful, for example:

Using statistics to apply it to experiments we will use later on in careers in psychology. A practical course.

Others suggested that statistics could be applied in real life:

It is an attempt to give psychology students insight into stats & experimental method, to enable them to do psychological research if they choose to follow psychology as a career.

***Critical thinking* (3%)**

This category was the most expansive. The category indicated conceptions of statistics as providing a perspective on the ways in which data is used to make decisions - a scientific way of thinking and communicating. Responses in this category showed insight into the complexity and limitations of statistical theory.

Stats is about methodology which is used as a comprehensive form of analysis to interpret and test theories & correlations psychologists create. Substantiated method.

The majority of students held conceptions of statistics that were fragmented; disconnected from other knowledge and disjoint from their goals and lives. Reid & Petocz (2002) assert that 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 overstated".

Table 2 shows the percentages of students whose conceptions of statistics were classified in the five categories broken down into "Yes" students (students studying statistics willingly) and "No" students (students indicating reluctance). The percentages shown are column percentages, that is out of 71, 204 and 279, respectively. They are rounded to whole numbers except where the percentage is less than 1%. Each student's response was categorised into one and only one category. The final column summarises the overall frequency distribution for the participants in the five categories. Table 2 reveals the structural differences between the conceptions or experiences of students reporting that they were studying statistics willingly and those who reported reluctance to take the subject. The majority of the "Yes" students indicated awareness of the relevance of statistics to work as a

psychologist or even scientific thinking (*Tool* and *Critical Thinking* categories). On the other hand almost three quarters of the "No" students expressed interpretations of statistics in the first three categories, mostly indicating statistics as being about classroom learning.

Table 2. Number and percentage of "Yes" students and "No" students in each conception category

Category	"Yes" Students (N= 71)	"No" Students (N=204)	Total (*N=279)
NO MEANING	0	11 (5%)	11 (4%)
PROCESSES	7 (10%)	61 (30%)	68 (24%)
MASTERY	17 (24%)	75 (37%)	93 (33%)
TOOL	35 (49%)	36 (18%)	71 (25%)
CRITICALTHINKING	6 (8%)	1 (0.5%)	7 (3%)
Unclassified conceptions	6 (8%)	20 (10%)	29 (10%)

** Note four students could not be classified as "Yes" or "No".*

4.5. VIGNETTES FROM STUDENT INTERVIEWS

The five categories outlined in section 4.4 describe collective conceptions. That is, the categories have been "stripped" (Marton & Booth, 1997, p. 114) of the individual voices from which they were developed. The following excerpts are from interviews with selected students (reported in Gordon, 1999) and illustrate some of the individual interpretations of statistics captured by the conception categories.

The responses given by Narelle and Ben, below, are both indicative of the *Processes* category. The excerpt from Ruth's interview illustrates the *Mastery* category, as her focus was on understanding and mastering the concepts for examination purposes. Tilly, in her interview, indicated an awareness of the use the statistics she was learning (*Tool* category), while Tessa's interview responses illustrate the most expansive conception of statistics (*Critical Thinking* category).

Narelle (Processes)

Narelle indicated that learning statistics was associated with anxiety and a lack of confidence. Although she had studied a one-year, introductory statistics topic for Arts students the previous year at university this had added to her confusion rather than demystifying statistics. She reported her experience of studying statistics as follows:

> *I usually come home and have a look at what we've done in class and hope I understand it. If I don't then I'll perhaps contact my tutor, which I've only done once, or just keep doing the exercises until I work out what's going on.*
>
> *... I want to be able to do it automatically rather than it be such a difficult process. ... I'd find what I need out of the problem, the mean and whatever, and then work through that - rather than read so much into the problem; what's going on with the rats or whatever.*
>
> *... I'm trying to get the relevant information from the problem without being distracted by so much to think about, like the whole experiment. ...*
>
> *I don't enjoy it particularly. I enjoy it once I get an answer out I guess, but the working out is just not my thing. I'm not a very mathematical person.*

Narelle's comments indicate a focus on the mechanics of problem solving without considering the context of the problems, which fits with a conception of statistics as being about processes. Her negative feelings about learning statistical concepts appeared to be linked to her lack of confidence in mastering mathematics.

Ben (Processes)

Ben, like Narelle expressed a focus on getting the answers without much attention to the meaning of the statistical theory, but, unlike Narelle, he indicated a facility with learning statistical processes. He wrote in his survey that his aim was to "be able to get the right answers". In his interview he said:

> *It doesn't so much interest me, but its easy going. You don't have to muck 'round doing reports and stuff. You can just learn it. And it's sort of half relevant to what I'm doing, and that's fine. It doesn't bother me a great deal if I don't understand, say, the exact theory behind different distributions and stuff like that. It doesn't really concern me a great deal. As long as I understand the basics and be able to just get through the questions.*

Ruth (Mastery)

In her interview Ruth indicated that statistics was irrelevant to her, observing that "this manipulation seems to be a little bit pointless. We're never going to have to use it again." However Ruth revealed that she was trying to achieve good grades by understanding the concepts and methods. Hence, Ruth's focus appeared to be on the mastery of ideas and skills she was taught in class.

> *It's more trying to understand. It's more trying to give an understanding rather than just answers. It's not just the answer on the page. It's understanding how you get to it. … You can write down and explain it rather than just having to use formulas.*
>
> *I was hoping that in the exams — that at least I'd have remembered something, that it would stay there. But other than that, it (the knowledge) is not doing anything.*
>
> *I'd like to understand it for next year. I don't want to have wasted time. To have nothing to show for it. And have no added knowledge or no added systems of doing things. It would be nice to have learned some logical ways — some logical methods. But it would be nice to pass the exams. Just that.*

Ruth explained that she seldom practised using the statistics, rather concentrated on "trying to get it to stick in my head".

Tilly (Tool)

Tilly's focus on statistics was on the application of knowledge. This represents a shift in focus from the processes of statistics and mastery of skills and concepts to an awareness of statistics as being useful in the real world and relevant to professional psychologists. This focus on statistics as a tool was expressed in Tilly's remarks on how she learned statistics.

> *When I'm trying to summarise my lecture notes I try to integrate all the information I have on each set topic. And understand that and therefore know how to apply it. What we're doing this semester is a lot more real statistics, how you really apply statistics to what you're doing. I think that's how psychologists would go about testing and researching these things. I want to learn it because I'm going to need the knowledge. And also - in a lot of ways it overcomes my frustration I had with maths last year. So it's a triumph, almost, to have overcome that big barrier to statistics that I had built up last year.*

Tilly appeared to be trying to make connections and see the big picture rather than learn isolated and decontextualised concepts.

Tessa (Critical Thinking)

Tessa expressed a high level of engagement with learning statistics and insight into statistical knowledge. In addition to indicating an awareness of statistics as a tool, which could be applied in professional life, Tessa's comments demonstrate an understanding of the basis and communication of scientific thinking. An excerpt follows:

> *It's very interesting - how statistics moulds itself into psychology. Right now I think psychology's trying to become a science because of the emphasis that people put on science being the main area of knowledge. The way statistics moulds itself into psychology kinda gives psychology a*

basis. Like - how would you put it - like raw facts that can be analysed scientifically, I guess. In maths at school there wasn't that much application to things in real life. A lot of it was just formula based, following the formulas, plugging in the numbers. With statistics, however, you've got an aim. In a real life situation, in society - statistics is like a tool to analyse whatever happens when you do experiments. ... It's helped me think more logically. Like inductive reasoning. It's a lot like inductive reasoning. You come up with a hypothesis and you have to follow through in order to get an answer. ...

I guess that's one of the main reasons I chose psychology and philosophy. I wanted a broader view of life. Science and maths in high school was more a regurgitation of theories. I just thought that in psychology and philosophy I might be able to contribute some new ideas.

4.6. INTERVIEWS WITH TWO TEACHERS OF PSYCHOLOGY STATISTICS: WENDY AND CATHY

Teachers are arguably the most important influences on student learning and send messages instrumental in shaping the experiences of their students. Teaching is organised in an institutional context that may constrain or encourage preferred ways of teaching. The following excerpts are from two teachers of psychology statistics. The excerpts express what Cathy and Wendy perceived to be the purposes of including statistics in psychology, their methods of teaching and the constraints and institutional features which shaped their teaching.

Cathy saw statistics as a tool for research as well as a way for students to critically assess information. She described the aims of the statistics course in this way.

***Cathy**: First of all, in reading the literature, understanding what other people have done in their experiments and secondly to help them if they carry out their own research as well, to understand how we have to make sense of numbers and what we do with statistics. To help us make sense of it.*

Cathy hoped that what students would get out of the statistics course was:

Well, just an understanding of the place of statistical procedures within the overall research approach in psychology. So, not to see it as something completely separate but to see how to use it as an aid to systematic thinking and detecting effects amongst all the noise, that sort of thing.

Wendy related statistics to further study but also drew on her own experiences to explain the place of statistics in students' ongoing lives.

***Wendy:** I see it as giving little tastes of what you can do. Building up perhaps to the third year course. The purpose in any course is to lay the ground-work for:*

A) those who want to go on further in your traditional, academic research oriented stuff and

B) for those who don't want to go on further but are basically getting a degree so that they can then move into a large company. To basically lay the framework so that when things do come across their desk they can understand it.

It sounds trite but I've got friends who have done that - moved into banking or market research or whatever, and are having troubles in terms of colleagues who are not understanding:

'What's an average? What's a distribution?'

Even if the students don't remember how to do a chi-squared test, they'll know what a population is. And what the point is - we're trying to tell whether this is having an effect.

I asked Cathy and Wendy how they tried to achieve these educational aims for statistics in their teaching. Their responses showed that they both regarded concrete examples as of prime importance in helping students understand the concepts. Cathy drew on textbooks for her source of examples while Wendy evidently tried to motivate her students by linking her examples to students' everyday lives.

***Cathy:** I suppose it depends which topic we're talking about. In general, I try and do it with examples, instead of doing it in the abstract. I relate it to actual examples of when these problems*

might arise and how we're going to cope with these sorts of numbers. What we're going to do with them - and understand why they're going this way or that way.

Wendy: *What I try to do is give them an overall feeling for what they're going to do. For example with chi-square tests. Not all data is continuous. Sometimes it's: 'Do you like Pepsi, or do you prefer Coke?' And that sort of data is just as interesting. However, you treat it differently because you can't build up a number line. It's just: 'Yes' or 'No', or maybe you've got more categories. Give them an overview like that. Give them an overall spiel about when would you use it. Try and come up with examples that are interesting. For example, to make multiple regression interesting you can try and predict who's going to win the Melbourne cup (horse race). And change the equation: 'This is a new jockey, this is his weight, this variable is: Has the horse won the Caulfield?'. And it's quite amazing then how you'll get to the people at the back of the room. And then move onto question and answer time.*

The above comments of the two teachers indicate that each had a different sense of what it means to learn statistics. This difference emerged more clearly from their reports about how a student's understanding of statistics was assessed. Cathy indicated her dissatisfaction with multiple choice examinations which were a resource issue.

Cathy: *I think our best feedback comes from the tests rather than the exams. The exams are multiple-choice and I don't really think that multiple-choice exams are a wonderful method of assessment. They're just essential for financial reasons. I think it's in the test that you get the most feedback about what they're understanding and what they're not understanding. What they can do with it. Whether they can draw appropriate conclusions. You see a lot of the little things that they're not understanding by looking at how they perform in tests.*

Well, things like in hypothesis testing - just whether they can - given a critical value, an observed value, can they work out what they had to do with it? And then what conclusion they can draw having decided to accept or reject the null hypothesis. That's a funny whole cycle that they can often be confused about. Three different parts. Once you can force them to write out their answers, you can see if they're understanding it. And if they can apply formulae. Which is tedious and will probably become less and less of a necessity as courses become more computerised. So the emphasis will become more on understanding output of the procedure I think.

Cathy's observations seem to show that her emphasis was on assessing skills and procedures, although she acknowledged that the time for such procedural learning was past. Wendy appeared to be more concerned with the future relevance of the concepts being learned and indicated that rote learning was a stepping-stone to conceptual understanding.

Wendy: *I think with stats, a lot of it is rote learning and it is very dull - until you actually get to do it yourself. I was no brilliant stats brain at university but once I started working it had a point. So that's what I try and do. I always try to bring it back to something tangible. Otherwise it does get to be: 'Okay, just write down the answers and we'll learn it later'.*

The two teachers' differing evaluations of the procedural part of statistics versus the interpretative component indicated by the above comments are also demonstrated in their observations, below, comparing the performances of students enrolled for Science degrees to performances of Arts students. Cathy reported that she had taught tutorial groups which, because of timetable constrictions, were predominantly made up of Science students.

Cathy: *You tend to get concentrations of science students in certain tutorials because of timetable constraints and they just stand out. They're so different to the Arts students because they're not scared of formulae. They can deal with it. I was astounded with this group I had last semester. They had it. They could do it. Then I went straight into a predominantly Arts tutorial group. It was a whole different story. It was just much harder for them. That was the main, obvious, difference.*

Wendy: *Very definite differences between Arts and Science students. The Arts, with 'Arts' in inverted commas - your heavily, language based people, tend to get a lot more into analysis at the language level. But your general Arts students will tend to be fazed by the sigma and other symbols and basically a bit number phobic at the beginning. However, they're very good at interpreting results. They're good at telling you what's actually going on. Whereas the Science*

students tend not to worry at all. It doesn't faze them - all the Greek letters, etc. etc. or the subscripts or the algebra, but they're not very good at drawing conclusions. I think that in your traditional physical sciences - what's there is there. You don't have to interpret it. You just report: 'We rejected', or 'This is from a different sample'. Full stop. Well what does that mean? So the different abilities of these groups tend to balance out.

These comments of Cathy and Wendy are particularly interesting in view of Ben's assessment of statistics (excerpt in section 4.5). Ben's responses indicate a focus on and an ease with the procedural part of statistics and he appeared to be content to report results without much thought about the interpretations.

The institutional setting shapes educators' activities as much as it does students' perceptions and actions. Cathy and Wendy agreed that a shortage of teaching time for statistics was a major constraint.

Cathy: *Well, I think in our course students are disadvantaged. In other courses, apparently, they have a lot more time to spend on statistics. They have, I know, at another university, two hours a week of lectures, an hour of tutorials and an hour using computers. They have a different structure to their degree so they can manage their time. Our students are asked to absorb a lot in a short space of time. They do reasonably well at it.*

I asked Cathy and Wendy whether they felt the statistics course could be improved by having more time spent on it.

Cathy: *Yes, but I don't see where the time is coming from. It's an impossible limitation.*

Wendy: *I think with the second year statistics course it could cover more ground than it does. Not in terms of the time we have now. But I think we do need two lectures a week and two hour tutorials. You don't get enough time. You don't get enough time to sit down ... . You've got thirty minds in a tutorial and everyone's going in different directions. Now if you're lucky, fifteen of them will be with you. But of course it's hard when you're up there.*

In addition to lack of time, Wendy felt the lack of opportunity for students to apply statistics was a further constraint and hindered students from seeing statistics as useful and relevant to the field of psychology. Wendy saw this as partly due to students' insufficient statistical knowledge at that stage of the psychology course.

Wendy: *Stats to me was just something you did - until I was actually working. And then it became relevant because it was my stuff. It was my data. What I would like to see is an integration, perhaps, with other areas - social psychology, learning, etc. etc. In that you can do an experiment and apply your own statistics. Unfortunately, my experience, having taught 'Learning' in second and third year, is that, of course, experiments that you run are too complicated for the stats that they know. But I think that you could present them with a data set that could be analysed. Chi square tests are very useful. I think that's where it needs to be tied in, rather than having very discrete parts. I think in second year every unit is very separate: 'Here's your Statistics (topic). And here's Social Psychology. And here's the statistics we've done for you'.*

Cathy concurred with Wendy's view that a lack of statistical knowledge constrained students' understanding of its application:

Cathy: *I think that probably they don't have a clear idea (of statistics) yet. They haven't done any research yet and a lot of them aren't even reading the publications in the literature. They're just reading the general text-books or whatever, so I think they're not really yet able to have an overview of what it's all about. How they might ever be able to use it. Usually they haven't got a clue what to do anyhow, but also any analyses that come up in other areas of the course are more complicated then anything they've covered yet in their actual statistics course. It's hard to coordinate between members of the department.*

Wendy was explicit in stating her aims to students. One of her aims was that students should feel confident enough to use their statistics, irrespective of how it looked "on paper".

Wendy*: I tend to go in at the beginning of every semester and introduce myself and say:*

'Alright, we're going to do this in various ways. One way is to get you through the exams. One aim of mine is - if you are interested - to go further on with it. Another aim of mine is to get every

single one of you up to a level where, alright, on paper you might not be brilliant but you feel competent enough to sit down and understand other things that you might be reading'.

Both teachers expressed enthusiasm for teaching statistics. Cathy described her perceptions of the rewards of teaching statistics as follows.

***Cathy**: I love it. I love teaching statistics. The rest of psychology is so waffly in many ways. I feel statistics is just less so. Every year I have at least one student come up to me - I had one this week - and say: 'I don't know how you can bear to make a career out of teaching statistics'. But I really enjoy teaching it and I enjoy the gratification when they understand it. You see that they've gone from not understanding it to understanding and their own satisfaction in mastering it.*

Wendy related to her students by recalling her own experiences of learning statistics:

***Wendy**: The thing that I have to remember is how I learned it. And before you go into a class you've got to think: 'Okay, where are people going to go wrong?' And second guess the points at which they will. Spend a lot of time clarifying it. I think what's changed is my perception of how useful it is. I think that I would have had a much easier time in fourth year and in my initial working years if I had learned it. And thinking about it now, I did waste a lot of time. Sure I got through. But it is a very easy subject. And I always point out when students say: 'Oh I can't learn this'. 'You can learn it. The point is whether or not you will'. But of course it's all mixed up in this aura of: 'Oh it's maths.'*

Wendy's expressions are in accord with the view of activity theorists (Leont'ev, 1981) that goals are the primary elements in determining how and what learning takes place. Wendy clearly empathised with her students' lack of enthralment with statistics and was aware that some students identified statistics with mathematics, as was reported in section 4.1. However, her own experience of using statistics enabled her to see its potential for enhancing the perspectives of students in their future lives.

***Wendy:** What do they take away from the second year statistics course? I mean the formulas are gone by Xmas. Right? What I think stays is the concept of the underlying populations — the difference between looking different and being significantly different. But I'm not sure you can measure that. I think where that comes out is in their third year. When they go and read papers and do have a feel for an experimental hypothesis and a null hypothesis. Unfortunately we can't tap into that until further down the track. The students can't tap into it until they sit down and have that 'Aha!' experience. The realisation that: 'I do know what they're talking about!'.*

The theoretical framework I have developed highlights the need to recognise that the classroom is not just a place where instruction is received, but a social structure in which students' and teachers' actions form and transform. Students' and teachers' actions relate to their histories, goals and experiences and the social and cultural environment in which teaching and learning take place. The interviews with Wendy and Cathy provide some insights into this environment.

5. CONCLUSION

The aim of this paper was to bring to the foreground the taken-for-granted context of statistics as a service course and students' experiences of the subject. The report focused on psychology students' feelings about learning statistics and their interpretations of statistics. The results could alert researchers and teachers of statistics to look at the 'big picture' or system that surrounds statistics service courses and the qualitative variation in students' awareness of statistics - the diverse meanings of statistical knowledge to students.

The majority of the students who were surveyed in this study were unwillingly studying statistics at university. They reported learning mechanical procedures or mastering decontextualised statistical concepts and methods. A minority group of students expressed a greater willingness to participate in the statistics course and reported more thoughtful and personally meaningful conceptions of statistics. The latter group also achieved higher grades. Statistics educators, Cathy and Wendy observed that a lack of awareness of the functionality of statistical skills and processes made it difficult for the students to experience statistical thinking as personally meaningful. Their comments indicate the

tensions that underpin efforts to engage students in meaningful statistical learning for their profession and the contextual, organisational factors impacting on teaching statistics as a service course at university. Carvalho, (2002) reiterates that changing the focus from calculations and techniques, the "reality in the classroom", remains a challenge for statistics teaching in the future.

An important component of the learning environment is the way statistics is taught. The interviews with Cathy and Wendy indicated their different perspectives on teaching and learning statistics in a psychology course. These data raise questions for further research. What are the diverse conceptions of statistics, attitudes to teaching statistics and teaching strategies of service teachers? How do teachers' different beliefs about and positions on teaching statistics in service courses relate to student learning, including students' ongoing developments of conceptions of statistics?

A further direction for research indicated by this study is the investigation of organisational frameworks that could promote active learning and help students develop positive attitudes to learning statistics. Cobb (1993, para. 82) asserts that:

> *Learning must be active if it is to build a student's sense of responsibility for the process; lecture-based courses undermine the student's sense of responsibility for learning.* The teacher is neither producing a course for the student nor producing a student for an employer. Both these models make our students passive consumers rather than active constructors of their education.

Although the traditional lecture format and delivery of information model that Cobb (1993) deplores remains the mainstay of some statistics courses, alternative and diverse ways of thinking about statistical learning have been emerging. Research on problem-based learning methods in a graduate biostatistics course (Boyle, 1999) indicated that most of the students perceived that their overall understanding improved greatly with this approach, although more time and effort were required. There were also some indications that the problem-based course helped students develop suitable analysis plans for their research data and decreased their anxiety. Garfield (1993) reviewed the use of small group cooperative learning in statistics classes and advocated research in this area. Mohammad Yusof and Tall (1999) showed that a mathematics course encouraging cooperative problem solving and reflection changed students' attitudes in a desired direction. That is, changes were from the negative attitudes teachers had come to "expect" from students towards attitudes "preferred" by their teachers.

This paper indicates some major issues for statistics education in the context of students learning statistics as a compulsory service course. Challenges include providing students with learning experiences which enable them to reinterpret statistics as personally meaningful knowledge rather than a culturally "necessary" body of skills and concepts and changing conceptions of statistics from classroom exercises in which "computers do all the work" to a tool for use in professional and individual life. Service courses in statistics could provide opportunities to connect professional statisticians and occasional users and to induct undergraduate students into the community of statisticians.

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