Students' Orientations to Learning Statistics – Profiles of Experience

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In this study I look at university students' orientations to learning statistics – how they feel about learning it, their conceptions of the subject matter and their approaches to learning it. I use complementary methods of analysis to understand the relationships among students' appraisals, conceptions, approaches and attainments on assessments. The findings reveal underlying dimensions of the variables and present dramatically different profiles of students' experiences. Students' learning is linked to a complex web of personal, social and contextual factors.

Introduction

The literature on statistics education shows that many students have a poor understanding of statistical concepts (for example, Garfield & Ahlgren, 1988). One aspect that is likely to contribute to students' difficulties in the subject is the way students constitute the subject matter as a whole — their understandings of the content presented and how they experience learning the subject in the context in which it is presented. Previous research on the quality of students' learning of mathematics or statistics at university indicates the need to explicitly address the relationship between the student and the learning context (Crawford, Gordon, Nicholas & Prosser, 1994; Gordon, 1995; Williams 1993). Hence, an important step in furthering understanding of student learning within the subject field, statistics, is to consider students' views of statistical knowledge and how these relate to other aspects of their learning and performance.

In this study I look at university students' orientations to learning statistics as a compulsory component of second year Psychology — how they feel about learning it, their conceptions of the subject matter and their approaches to learning it. Preliminary findings have been reported in Gordon, Nicholas and Crawford, (1996). In this paper I build on my earlier analysis. I use complementary methods of data analysis to understand the relationships among students' appraisals of learning statistics, their conceptions of the subject matter, approaches to learning and attainments on tests and examinations. Factor analysis is used to explore the relationship between the variables. Cluster analysis shifts the focus from variables to students, identifying groups of students with similar profiles of experiences in learning statistics. The findings show striking trends and inter-dependencies among the variables and reveal cogent differences in students' experiences. Vignettes from interviews with selected students are used to illustrate two different profiles. These indicate that while the subject matter presented, institution and teacher were the same for the students surveyed, the students' awareness about their learning links a complex network of individual, social and contextual variables.

Method

Second year Psychology students at the University of Sydney were asked to complete a survey on learning statistics. The survey was completed halfway through semester one, during the statistics lecture, with the kind cooperation of the lecturer concerned. The survey consisted of questions relating to demographic variables, such as age, gender and prior level of mathematics studied, three open ended questions and a Likert type questionnaire — the Approaches to Learning Statistics Questionnaire. The study was approved by the University of Sydney Human Research Ethics Committee. The three open ended questions were as follows:

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.*

These open ended questions were followed by the Approaches to Learning Statistics Questionnaire (ALSQ). The questionnaire was modified from the Approaches To Learning Mathematics Questionnaire (Crawford et al, 1995), which in turn was derived from the Study Process Questionnaire (Biggs, 1987). The ALSQ consists of two scales, the Deep Approaches Scale and the Surface Approaches Scale. An item from the Deep Scale (item 24) and one from the Surface scale (item 7) are shown below.

Item 24. I believe strongly that my aim in studying statistics is to understand it for my own satisfaction.

Item 7. I learn some things in statistics by rote, going over and over them until I know them by heart.

Interviews with selected students were carried out in order to flesh out and clarify the survey responses.

Participants

The survey was completed by 279 Psychology II students. Almost three quarters of them (203 students) were female. Most of the students were either 19 years old (48%) or 20 years old (18%), though a sizeable minority (16.5%) were at least 25 years in age.

The prior level of mathematics studied by the surveyed students was higher than is often assumed for psychology students. Almost one quarter (68 students) of those surveyed had studied mathematics at university, most of these having completed a first year mathematics subject at the University of Sydney. Of the rest, almost all (163) had written the final school examination in mathematics for New South Wales, called the Higher School Certificate (HSC), at one of the three highest levels of the five levels offered in mathematics. These three levels include the study of Calculus. Twenty six students had not taken mathematics for the HSC. These were almost all mature students, with twenty two of them being 25 years old or older.

All the surveyed students had completed a brief (about five weeks) introductory course on statistics in first year Psychology.

Results

In what follows, the term "Statistics" with a capital "S" will be used to denote the statistics component of second year Psychology being studied by the participants in this research project.

Willingness To Learn Statistics

The teachers of this topic have an unenviable task. Most students (73%) reported that they would not have studied Statistics, had they been given a choice. This finding complements research by Ainley et al (1994). They investigated the subject choice of Australian students in the final two years of school. They found that those who reported a high level of social interest, defined as interest in nurturing or helping others, had low interest and participation in mathematics and the physical science subjects.

The reasons reported most frequently by the students who expressed willingness to study Statistics, were that statistics was useful — for the study of Psychology or other subjects or higher degrees, for research or for general "real world" applications. On the other hand, students who were reluctant to study Statistics reported their reasons for this in terms of its lack of appeal — to them the subject was boring and hard and they did not enjoy it. Hence, rather than reflecting opposite sides of the same coin, the reasons given by students willing to study Statistics related to extrinsic factors, while the reasons given by the reluctant majority related to personal or intrinsic considerations.

This has important implications for the teaching of statistics as a service course. If educators stress the usefulness of the subject to their fields they may be preaching to the converted. Students' subjective evaluations in terms of interest and affective elements need to be addressed too.

Conceptions Of Statistics

Five categories emerged from the analysis of students' responses to the open ended questions, particularly Question 3. I called these categories NO MEANING, PROCESSES, MASTERY, TOOL and CRITICAL THINKING. Table 1 summarises the Conception

categories and illustrates each category by means of a representative excerpt from a survey. (See Gordon, Nicholas & Crawford, 1996, for more details.) With the exception of the first category (NO MEANING), the categories for students' conceptions form a hierarchy in terms of inclusiveness. That is, I am inferring that for categories 2 to 4, higher categories logically include the awareness expressed in lower categories. A response classified in a higher category indicates to me an awareness of the conceptions described in the lower categories, but shows added understanding. This is a logical hierarchy. Empirically, too, many students' responses indicated a conception of Statistics that encompassed two or more of these four categories. In these cases their conceptions were classified into the "highest" of the categories indicated. Finally, although the merit of the conception was not used to determine the hierarchy, the higher categories can be seen to express more educationally desirable conceptions of Statistics than the lower ones. Statistics is taught as a service course. The teachers of it hope that students will find it a useful tool and one that will have impact on the students' lives and continued learning.

TABLE 1
CONCEPTIONS OF STATISTICS : LEVELS OF AWARENESS

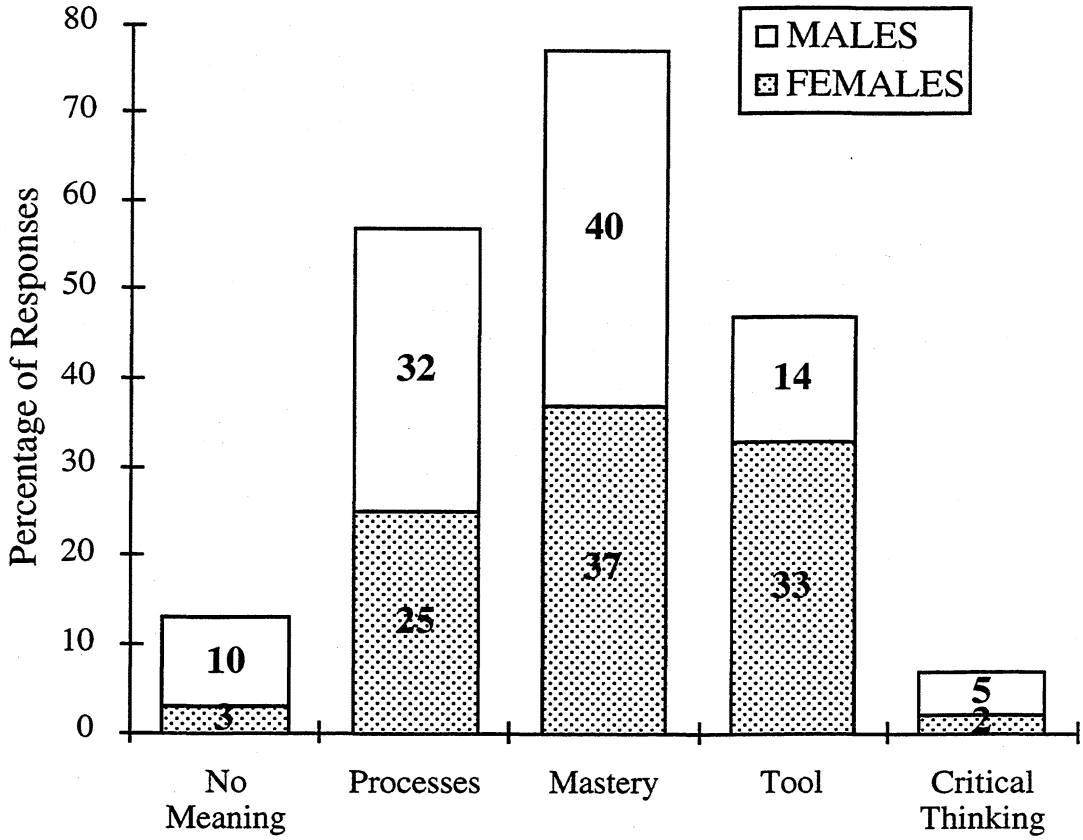
CATEGORY	VIEW OF KNOWLEDGE EXPRESSED BY CONCEPT	EXAMPLE OF RESPONSE
1. NO MEANING	imposed, irrelevant	*You tell me, I just learn.*
2. PROCESSES Mechanical techniques or algorithms	disconnected, for reproduction in assessments	*... You don't have to understand how it works, just be able to get the right answer.*
3. MASTERY reading and understanding material as presented in class	information to be accumulated and stored in order to meet the demands of assessments	*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.*
4. TOOL knowledge for use	could be applied in real life	*It is trying to teach how statistics is used in everyday research in psychology. It's relevant to most future careers.*
5. CRITICAL THINKING a perspective on the ways in which data is used to make decisions.	a way of thinking and communicating; insight into the complexity & limitations of statistical theory	*Stats. is about methodology which is used as a comprehensive form of analysis to interpret and test theories psychologists create.*

Distribution of Responses The distribution of students' reported conceptions into the five categories is shown below in Figure 1. The percentages shown in the bar graph are presented separately for males (N=63) and females (N=186). As can be seen, the modal category for both males and females was MASTERY. Only six students (3 male, 3 female reported conceptions of Statistics which were classified into the highest category: CRITICAL THINKING.

The gender differences are particularly interesting here. Male students tended to see the Statistics in terms of academic exercises. Only 14% of them (9 students) compared to 33% of the females (62 students), perceived the subject as applicable to "real life" (TOOL).

FIGURE 1

DISTRIBUTION OF MALES' AND FEMALES' REPORTED CONCEPTIONS OF STATISTICS



Percentages rounded to whole numbers.

Performance In Assessments

The final mark for Statistics was the average of the following four components: the class mark and examination mark for semester one and the class mark and examination mark for semester two. The examinations both consisted of multiple choice questions while the class marks were based on open book quizzes. Males outperformed females in Statistics achieving a final mean score of 63.9% compared with the females' mean of 56.6% ($t=2.58$, $p<0.05$). This difference was due mainly to the superior performance of the males in the multiple choice examination in semester one. One finding explodes the myth that ability in the general area of Psychology and prowess in Statistics are mutually exclusive. There was a strong correlation of 0.62 ($p<0.001$) between students' final marks in Statistics and their average marks for the other areas of Psychology II.

Differences in Students' Experiences of Learning Statistics

Females scored significantly higher than males on the Surface scale of the ALSQ ($t=-3.2$, $p<0.01$). Scores on the Deep scale did not differ for males and females.

On average, scores on the Deep scale increased with each increase in category of Conceptions (from 1 to 5). The mean scores on the Surface scale decreased with each increase in Conception category, with the unexpected exception of the NO MEANING

group. I had anticipated that the students who conceived of Statistics as a meaningless and pointless subject would tend to adopt surface approaches to learning it. This proved not to be the case, although these students did have low scores on the Deep scale. This anomaly led me to inspect more closely the NO MEANING students' responses to the second open ended survey question, which asked them about their strategies for and intentions in learning Statistics. This revealed that these students evidently did not engage with the task. They were not attempting to memorise or rote learn the material presented, they simply made the minimal effort required. As one of them wrote in response to Question 2a, her strategy was to: "ignore it until I have to study for a test".

I then carried out a factor analysis to determine the separate constructs underlying a number of variables in the study. The following variables were included: Concept categories 2 to 5 (excluding the NO MEANING category, since it is not logically or empirically part of the hierarchy as supported by the previous finding), willingness to study Statistics (CHOICE: N0 1, YES 2), marks in tests and examinations (CLASS1, EXAM1, CLASS2, EXAM2), scores on the deep and surface scales of the Approaches to Learning Statistics Questionnaire (DEEP, SURFACE), Age in years (AGE) and gender (GENDER: MALE 1, FEMALE 2).

Four factors were extracted, using a principal components analysis with varimax rotation. These had eigenvalues 3.82, 1.63, 1.18 and 1.10 respectively. The four factors accounted for 70.3% of the variance (34.7%, 14.8%, 10.8% and 10.0%). The rotated factor matrix showing the loadings of the variables on the factors is shown in Table 2.

TABLE 2

ROTATED FACTOR MATRIX

	PERFORMANCE	ORIENTATION	GENDER	MATURITY
CONCEPT (4 categories)		78		
CHOICE (No 1, Yes 2)		71		
SURFACE		–67	31	
DEEP		67		
EXAM1	81			
EXAM2	82			
CLASS1	84			
CLASS2	83			
AGE				92
PRIOR MATHS		51		–51
GENDER (M 1, F 2)			93	

Decimal points and loadings less than 0.3 omitted. Decimals correct to two places.

As can be seen from Table 2, the first factor links the variables concerned with performance on assessment tasks. Interestingly, neither deep nor surface approaches loaded to any notable extent on this factor. The second factor shows the positive relationship among the variables for students' conceptions of Statistics (for levels 2 to 5), their willingness to study it, the level of mathematics studied previously and their scores on the Deep scale of the Approaches to Learning Statistics Questionnaire (ALSQ). Scores on the Surface scale of the ALSQ loaded negatively on this factor. The third factor indicates a link between females and surface approaches to learning Statistics, consistent with the finding reported earlier in this section. The final factor indicates that higher age is related to a low background in mathematics. This was the case, as described previously. I have interpreted the four factors as PERFORMANCE, ORIENTATION, GENDER and MATURITY.

In summary, an important outcome of this analysis was to establish links among: motivation to learn Statistics, higher levels of awareness about Statistics, better preparation in mathematics and deep approaches to learning, opposed to surface approaches. Performance on assessments emerged as a separate dimension to orientation. The factors derived are highly interpretable and consistent with findings arrived at by other methods.

Cluster analysis is a way of identifying subgroups of students (rather than variables) on the basis of similarity of scores on chosen variables. In order to complement the factor analysis by relating students' performances on assessments and their approaches to learning Statistics, clustering was done on the standardised variables (Z-scores) for: CLASS1, EXAM1, CLASS2, EXAM2, DEEP, SURFACE.

Profiles of clusters: Qualitative investigations (interviews and responses to open ended questions) suggested four different profiles of achievement and approaches. These were identified by cluster analysis (see Table 3). Differences between the means for the four groups were considerable and statistically significant ($p<0.001$) on the clustering variables..

TABLE 3

STANDARDISED MEANS FOR CLUSTERS ON ASSESSMENTS AND APPROACHES TO LEARNING STATISTICS

MEAN SCORES (Z scores)	CLUSTER 1 High Achievers Above Average on Deep scale (N=47)	CLUSTER 2 High Achievers Above Average on Surface (N=61)	CLUSTER 3 Low Achievers Above Average on Deep (N=42)	CLUSTER 4 Low Achievers Above Average on Surface (N=61)
*Final Statistics Mark	1.03 (77%)	0.62 (70%)	–0.36 (52%)	–1.12 (38%)
Z-Score: Deep Scale	0.98	–0.41	0.10	–0.36
Z-Score: Surface Scale	–1.06	0.38	–0.53	0.71

*Raw means in brackets. Mean mark in Statistics for surveyed students=58%, SD=18.5%.

The profiles of the first two clusters are particularly interesting. While both these groups of students achieved high marks in Statistics, attaining averages of 77% and 70% respectively, their characteristic approaches to learning were very different (see Figure 2).

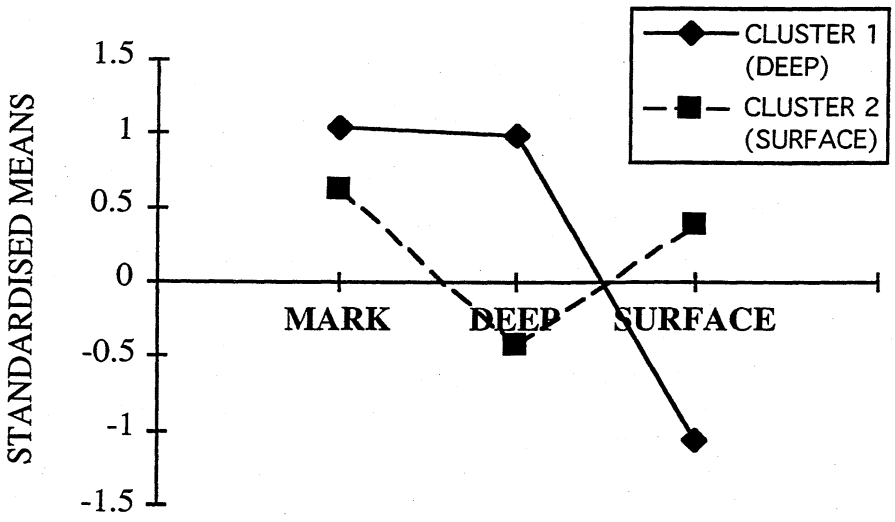
Cluster 1 is characterised by students who reported adopting primarily deep approaches to learning Statistics, rather than surface approaches. Unlike the other three clusters, most (54%) of the students in this group expressed willingness to learn Statistics. The most common category for their conceptions was TOOLS (53.5%).

The students classified in cluster 2 evidently had a facility for learning Statistics, while lacking the motivation or awareness of the subject of their colleagues in Cluster 1. Most (77%) of them reported reluctance to study Statistics. Their modal category of Conception was PROCESSES (39% of them), followed by MASTERY (32%).

Clusters three and four performed, on average, at a much lower level than the first two groups, attaining averages of 52% and 38% respectively. The profile of the Cluster 4 students is particularly dismal with 93% reporting that they would not have studied Statistics given a choice. These students reported adopting surface approaches to their learning. Most of them (55%) perceived of the Statistics as being about MASTERY of statistical ideas and skills.

Most of the males were in clusters 2 and 1 (38% and 30% of them, respectively) while females fell mainly into clusters 4 and 2 (33%, 26%).

FIGURE 2
MARKS AND APPROACHES FOR THE TWO HIGH ACHIEVING CLUSTER GROUPS



MARKS AND APPROACHES

Two Vignettes From Student Interviews: The profiles described above are of clusters, not individuals. Hence any individual learner may fit some but not necessarily all the characteristics of the cluster group into which she or he has been placed. The following excerpts are from interviews with two high achieving students. Tilly achieved a final mark of 87.5% on Statistics, while Ben attained 95%. As the extracts show, these two students had, however, quite different approaches to learning.

TILLY (Cluster 1)

> 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.

BEN (Cluster 2)

> 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.

Summary And Conclusion

This paper described the relationships among a number of variables in this study. These included demographic variables, the students' reasons for their willingness or reluctance to study Statistics, the categories for the students' conceptions of Statistics, their approaches to learning Statistics and their assessment results.

Most of the students were female and had studied mathematics at a level which included Calculus. The students were overwhelmingly adverse to studying Statistics, because they found it boring or difficult, though the subject was acknowledged as being

necessary for Psychology. A range of conceptions of Statistics were held by the students, but most thought of the subject as being about understanding the prescribed content and solving the problems presented in class, unrelated to the practice of psychology and isolated from the wider world.

The findings of this study present evidence of relationships among students' appraisals of learning Statistics, their conceptions of it and their approaches to learning it. It also shows that students' in the same class have strikingly different experiences of learning Statistics. In particular, qualitatively different orientations to and outcomes of learning Statistics were identified. Unfortunately the majority of the students were unwilling to learn statistics, had perceptions of the subject mainly in terms of accumulating knowledge for assessment purposes and surface approaches to learning it. While some of these students did well in tests and examinations it is unlikely that many of them will transfer their knowledge to other environments. For a small group of able students, however, the picture is far more satisfactory. In addition to achieving high marks, these students were motivated to learn statistics, showed an awareness of the applications of the subject beyond the classroom walls and adopted deep approaches to learning it.

This suggests that we need to take a systemic view of the learning environment. That is, we should consider not only the content and the presentation of statistics, but also how the students perceive it and the context in which it is taught. This is best summed up by Leont'ev: "Meaning mediates man's reflection of the world" (Leont'ev, 1981, p126). That is, individuals filter their experiences through their awareness of purpose or significance and it is this awareness that we need to understand in order to educate students of statistics.

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