From Phillips, Brian (Ed.), (1997) Papers on Statistical Education presented at ICME-8 (International Congress on Mathematics Education-8) Seville, Spain, July 14-21, 1996. Hawthorn, Australlia: Swinburne Press. ISBN 0 85590 753 3

TEACHING STATISTICS TO RELUCTANT LEARNERS

Sue Gordon
University of Sydney
Australia

Abstract

This paper uses the lens of Activity Theory to look at some perceptions of students who sought assistance with their study of basic statistics at university. I suggest that for statistics to be an effective link with other subjects we must aim to educate our students beyond competency. That is, in addition to teaching technical skills and abilities and assessing these against set standards we must aim to enhance students' statistical "capability" – the capacity of students to use their knowledge and skills in statistics creatively and confidently. I illustrate how I try to implement these ideas in my teaching.

Introduction

The Mathematics Learning Centre at the University of Sydney, where I work, was established in 1984 with the aims of increasing access to mathematics as well as improving the completion rates for students studying mathematics and statistics. Students of the university attend the Centre voluntarily to get help with a range of mathematics and statistics courses. One of the largest groups of users of the Centre consists of students studying statistics as part of other subjects, for example Psychology or Public Health. Statistics, which provides a tool for dealing with complex and real life data, appears to be an eminently suitable link between mathematics and other subjects. It provides a bridge between abstract concepts and processes and the physical and social world. However, many of the students I teach are not interested in mathematics or have little background in it. Some of them experience considerable difficulty learning statistics.

My research (Gordon, 1995) into these and other university students' learning of statistics is based on Activity Theory. This theory was developed by Leont'ev and is founded on the ideas of Vygotsky and other Russian psychologists (Leont'ev, 1981; Vygotsky 1962, 1978). Activity Theory posits a systemic view of human behaviour in which an individual's goals and subjective perceptions are interwoven with socio-historical factors. From this perspective, human learning is viewed as active behaviour mediated by interactions with the social world. We learn by our engagements with other

people and our environments. This way of looking at thinking and learning suggests that while teachers may try to emphasise the usefulness of statistics, no one can persuade a student of the power of a tool. This discovery depends on the student's experience of its functionality. The link between statistics and the real world must be in the mind of the learner.

My research aims to understand how students experience their learning of statistics. I then try in my teaching to enable students to view statistics as a relevant and meaningful part of their lives. In this paper I illustrate how I implement these ideas. This includes activities for a bridging course which aims to prepare students, who lack the required mathematical background, for their study of statistics at university.

Statistics – a link between mathematics and other subjects?

Many teachers of mathematics would agree with one or both of the following reasons for attempting to link mathematics with other subjects:

1) To make the mathematics that students learn more interesting and relevant to their lives.
2) To provide students of mathematics with a tool which they can use to understand, interpret and critique other subjects.

Underpinning both of these is the following primary aim of education – to enhance our students' perspectives on the world; that is, to enable them to gain insight into the physical and social world in which we live.

Statistics, it would seem is the ideal branch of mathematics for promoting these aims. It provides a link between abstract mathematical concepts and everyday life. At university level it is taught as a service course in many disciplines. Often it is taught by practitioners in fields such as Economics, Public Health, Psychology, Engineering or Environmental Studies, to name but a few. It is included as a component of these courses mainly to provide students with a tool for understanding their subject as it is situated in the real world.

Unfortunately, the literature abounds with evidence that "the introductory statistics course is the most widely feared course on most university campuses" (Cotts, 1994). The students who study statistics are often not interested in it. They may not have been successful or confident learners of mathematics at school and may expect learning statistics to be similarly daunting. Their perceptions of what statistics is and why they are learning it may not match those of educators or practitioners (Gordon, Nicholas, & Crawford, 1996).

Background to my research

My perspective is based on the assertion that students' views of statistical knowledge relate to their experiences of learning it as a whole. This view emphasises the need to shift attention away from considering teaching and

learning statistics as independent activities to a more systemic view of the learning environment. That is, teachers need to consider not only the content and the presentation of statistics, but also how the students perceive it and their own learning. This framework is based on the work of Vygotsky (1962, 1978) and Leont'ev (1981). It explains higher order mental processes in terms of individuals interacting with others within a social environment and cultural system. People develop a knowledge of the world on the basis of life experiences which have a social and political context. The social interests and preoccupations of a culture are not, however, automatically assimilated by individuals, but are monitored in terms of their goals.

Leont'ev (1981, p126) explains: "Meaning mediates man's reflection of the world". That is, we filter our experiences of socially organised practices through our awareness of their purpose and significance. The relevance of a learning task to the student provides the framework within which that student acts. Leont'ev's framework suggests that in order to link statistics effectively with other subjects we must first understand the learners – their goals, perceptions and evaluations of the statistics they are studying.

I shall attempt to illustrate the impact of each of these factors with examples drawn from my teaching practice. I am particularly involved with psychology students studying statistics who come to the Mathematics Learning Centre – arguably among the most "maths-phobic" learners of statistics at my institution. The excerpts quoted are from interviews and surveys of these students. I am not involved with the students' formal assessment in any way and work extensively with them during the year. The close personal relationship that I have developed with many students enables me to have more access to their thoughts and feelings than is usually possible for someone teaching statistics at university.

In the next two sections, I look at some perceptions of students who came to the Mathematics Learning Centre for assistance in learning statistics. I then propose educational goals for teaching statistics. The final section describes some of the activities we use in the Centre to implement these goals. Resources which I have found helpful in teaching statistics to reluctant learners are included in this description.

Understanding the reluctant learner of statistics

Leont'ev (1981, p. 60) proposes that goals are the "energising function" of the student's activity. Yet often, in practice, if not in educational theory, the goals of the students are assumed to be irrelevant to their actions and simply ignored. The following quotes from three second year Psychology students illustrate that the goals of students are integral to their approaches.

> Norman:
> I have a very pragmatic approach to university, I give them what they want. Arguably if I could guarantee enough knowledge to get ten (full marks) in the stats. tutorial test and the exam. and know that I forgot it all completely afterwards, I'd almost go for that course, 'cause that's what they want. I really do like knowledge for knowledge's sake, but my main motivation is to pass the course.

A second student, Vicki, expressed the idea that statistics, far from being essential to the application of Psychology, is an unwelcome intruder. In a survey she wrote:

> I don't even see the point. In psych. why must maths. infiltrate itself??? Studies have shown that those who have high maths. abilities have low or poor communication & perception skills – shouldn't psychologists be exceptionally perceptive & able to communicate well? It seems that if there aren't silly numbers to justify things then they aren't plausible in our computer/maths./ science promotive society.

In contrast Tessa reported an understanding of the use and application of statistics:

> It's very interesting – how statistics moulds itself into Psychology. Reading through the texts in Psychology there's a lot of statistical data. Data that's been ordered in a statistical way to make it more of a hard science. In (school) maths. 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.
>
> 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.

These three students report opposing goals which indicate quite different approaches to the learning of statistics. Norman regarded learning it as a commercial transaction, in which the aim is to earn the marks, while for Vicki outright resentment at having to study statistics would seem to prevent the task from assuming any meaning. Tessa, however, reports an awareness of the meaning of the knowledge.

Experiences

Part of the complex system brought by the learner to the task are his or her goals. Another aspect which will affect how the individual approaches learning statistics is that person's experience of statistics – at school or in other settings. University students' expectations of learning statistics in the educational context are often based on their appraisals of school mathematics. These are often regarded very differently to their experiences with "life" statistics. Consider the following extract from an interview with a mature age student who returned to studying after many years away from the education system.

> Ernest:
> As a hobby for years, I have followed the races. I don't bet very much, but when I do it I am a mathematical punter, I look at the percentages. So I relate to probability. Probability is effectively something that I use. I like the idea of comparing my percentages with those that the bookmaker has on the board, and at that level I have always dealt with statistics.

While no reluctance to engage with "real life" statistics was reported, Ernest indicated a quite different attitude to school mathematics.

> Arithmetic I didn't mind at all, but the moment it became more abstract, the moment symbols entered the scene, without a teacher who could relate it to the practical usefulness of it – he lost me. It became an exercise that I couldn't see mattered much to me, had relevance to what I wanted to know. I would stare out of the window. It went very much past me.

Hettie, a student who also had little formal schooling in mathematics said:

> I had accounting skills from running a business, so I was not completely innumerate. ... In second year Psychology, from day one, when we got the (statistics) handout, I was panicked – by the algebraic equations, everything. This was what scientists, astrophysicists do, not what I could do.

Beyond competence in statistics

Most students will learn to master statistical skills and techniques in order to meet the demands of assessment. The knowledge so gained, however, may be inert. The tool that has been provided is likely to lie forgotten in the tool kit. Further, if the main effort of teaching basic statistics at university is to pass on and assess a set of facts and skills without regard to students'

personal concerns, we can expect to perpetuate many students' reluctance to learn statistics and risk that reluctance becoming repugnance for some. The challenge for statistics educators is to find a way to communicate, so that students may be encouraged to apply their knowledge to other subjects and to participate in the high quality learning that is surely the goal of education in any subject.

If our aim is to educate students in statistics, rather than train them to master techniques, then the emphasis of the teaching shifts from content to meaning, from imposed applications to personal connections. If capability, rather than competence is desired, then we must assist students to monitor their own learning and that of their peers. We must enable students to develop their communication skills and learn to work with others to solve problems.

Statistics education should equip students to apply their statistical learning in new and unfamiliar situations and to critically assess the ways in which statistics influences how decisions are made in society. It should enable them to develop confidence in using information technology appropriately. Most importantly, it must imbue students with the desire to continue learning and applying statistics.

A practical implementation: What we do at the Mathematics Learning Centre

One of the functions of the staff at the Mathematics Learning Centre is to design and teach bridging courses. One of these prepares students to study statistics at university. The students attend the course voluntarily and often have no more than middle secondary school level mathematics. In this section I provide examples of the activities and of the resources I use in this bridging course or to supplement students' learning of statistics at university. These activities can be adapted to suit students at school.

- I have designed a number of small group activities in order to involve students in discussing and analysing statistics used in everyday life.

For example, students are provided with pamphlets supplied by motoring and traffic organisations (Roads and Traffic Authority, New South Wales, 1992, 1996). The pamphlets describe the method and results of a study (updated in 1996) on the safety of various different car models. The statistics are compiled from crash data and give driver protection ratings for each model of car. The protection rating is an indication of the liklihood that a driver of a particular model is hospitalised or killed after a crash has taken place. I ask each group of students to select four different models and assess the relative safety of each model in comparison to others of the same class

(for example, small cars, luxury cars, four wheel drives, etc.) and in relation to all other car models assessed in the brochure. The groups are also asked to comment on the way the information is presented and to report on the potential for bias in the study. Each group summarises and reports on their findings. This usually generates lively discussion within each group.

- Students are provided with Mathematics Learning Centre booklets (for example, Gordon, 1993a; Gordon, 1993b; Nicholas, 1990) which they can study in their own time and at their own pace.

These booklets assume very little prior knowledge and are written for adults in plain language. They include many concrete examples. Students often comment that it is reassuring to have their own copies of these booklets for later reference. A complete list of our booklets is available from the Centre.

- I assist students to gain an intuitive idea about the concepts of probability by using probability games, such as the "DIME Probability Packs" (Giles, 1988) and by solving real life problems.

The Probability Packs offer a range of 24 different classroom experiments involving shakers containing counters, beads or dice. There are also recording charts which enable quick and easy visualisation of the outcomes of 100 trials of an experiment. These games are easily organised in a classroom. They assist students to develop an understanding of many concepts in probability by provoking thought and discussion centred around simple, practical activities. We introduce more complex theory, such as Bayes' Theorem, by looking at actual data on the sensitivity and specificity of a test for a disease (such as a test for the HIV virus) and by posing questions about the "false positives" and "false negatives" that could arise from such a test.

- I introduce measures of central tendency and dispersion in ways designed to emphasise the concepts. This is achieved by by presenting concrete examples without using algebraic notation. Students work cooperatively and use computer software such as "Statview Student" (Feldman & Gagnon, 1991) or "SPSS" (Norusis, 1990) to explore the shapes of distributions.

In one activity, students, working in pairs, are asked to group some data into intervals of their choice and to draw appropriate histograms by hand and by computer. The data consists of birth weights of 20 babies born at a certain clinic. Students, working in pairs, are asked to estimate the mean and standard deviation of the distribution from their hand drawn graphs. They then compare their estimates with the values of the mean and standard

deviation calculated from the raw data, using a calculator or computer. They also compare their hand drawn histograms with those of other pairs of students and with graphs they produce on a computer. This generates discussion about how and why differences and discrepancies occur and which intervals and scales produce the most informative graphs for the data.

- We enable students to gain some awareness of the uses and limitations of statistics in our society by group discussions centred round data from the media and other sources of relevant data.

There are many real life data sets available on the Internet. A good place to start is by looking at the relevant sections of the Journal of Statistics Education (Dietz, 1996). The Journal of Statistics Education Home Page can be found on the World Wide Web at: http://www2.ncsu.edu/ncsu/pams/stat/info/jse/homepage.html.

- I have found the use of metaphors a strong means of encouraging students to link mathematics with their everyday life and experiences. The following example illustrates this.

Students find the notion of a confidence interval a difficult one to grasp. One appealing metaphor to conceptualise this notion was developed by a student, Bruce, after a group discussion on the definition and construction of a confidence interval for the mean of a given population. He likened a confidence interval to a net which one casts into the sea in the hope of capturing a fish. The net is not thrown out at random, but in the area where the quarry is thought to be, based on observation. However, one is not absolutely certain of capturing the quarry. The net may be too short, or it may have a hole in it through which the fish slips. Hence there is a probability, such as 95%, associated with the capture of the prey – but this probability is not associated with the actual whereabouts of the fish.

- I recommend text books which relate statistics to practical contexts. Three of these books are listed below.

"Statistics Without Tears" (Rowntree, 1981) introduces many ideas that students use in the study of statistics. It explains the underlying concepts clearly and uses very little formal mathematics. "Statistics – A Guide To The Unknown" (Tanur et al, 1989) consists of essays written by expert statisticians showing how statistics is used in many areas of society, while "Chance and Data – Investigations" (Lovitt & Lowe, 1993) provides the students with insights gained by practical investigations and demonstrations.

- I encourage students to monitor and regulate their own progress by writing about their learning, that is, by keeping statistics notebooks. I suggest that students use these notebooks to summarise the factual

content of the subject, including giving an overview of each of the topics presented and writing their own explanations of all formulae. My guidelines for the notebooks also encourage students to monitor their own learning – to consciously evaluate their own strategies and progress and to assess their current difficulties. In this assessment process students are the judges, not the judged.

For example, one student explained her general strategy and intentions for learning statistics as follows.

- Read text (book) first to get a schema of topic.
- Top up text notes with lecture notes.
- Do examples in tutorials, homework and text.
- Relate concepts to 'real world'.
- Not happy to rote learn – must understand topic and never understand if don't have a schema & can't relate to real world.

Conclusion

Activity theory suggests that the social and cultural context in which any learning experience is embedded is integral to the learning that takes place. Our teaching of statistics must take account of students' intentions, strategies and interactions – what students are actually doing to learn statistics, as well as what is presented to them.

The activities I use at the Mathematics Learning Centre are designed to provide opportunities for discussion and problem solving which do not always centre round the teacher. I avoid a competitive environment, timed paper and pencil tasks and over-reliance on the teacher as the authority. These may orient students away from personal meaning and capability. The discussions using real life data validate students' personal experiences and informal learning – their "life" statistics. In these ways I hope to provide opportunities for students to connect their learning with their other subjects and their broader social lives.

References

Cotts, J. (1994). *Factors influencing student performance in statistics.* Paper presented at The Fourth International Conference on Teaching Statistics (ICOTS 4), Marrakech, Morocco.

Dietz, J. (Ed.) (1996). *Journal of Statistics Education.* Electronic Journal available on the World Wide Web at: http://www2.ncsu.edu/ncsu/pams/stat/info/jse/homepage.html.

Feldman, Jr., D.S. & Gagnon, J. (1991). *Statview Student.* Berkeley, CA.: Abacus Concepts, Inc.

Giles, G. (1988) *DIME projects, probability packs a & b.* Stradbroke, Norfolk: Tarquin Publications.

Gordon, S. (1993a). *Introduction to probability theory.* Sydney: Mathematics Learning Centre, University of Sydney.

Gordon, S. (1993b). *Counting techniques.* Sydney: Mathematics Learning Centre, University of Sydney.

Gordon, S. (1995). A theoretical approach to understanding learners of statistics. *Journal of Statistics Education* (Online), 3(3) (available e-mail by sending the one line message: send jse/v3n3/gordon to archive@jse.stat.ncsu.edu).

Gordon, S., Nicholas, J., & Crawford, K. (1996). Psychology students' conceptions of a statistics course. In L. Puig & A. Gutiérrez (Eds.), *Proceedings of the 20th Conference of the International Group for the Psychology of Mathematics Education,* (Vol. 3, pp. 11-18). Valencia: Universitat de València.

Leont'ev, A. N. (1981). The problem of activity in psychology. In J. V. Wertsch (Ed.), *The Concept of Activity in Soviet Psychology,* (pp. 37–71). New York: M. E. Sharpe.

Lovitt, C. & Lowe, I. (1993). *Chance and data: Investigations.(Vol 1.)* Carlton, Victoria, Australia: Curriculum Corporation.

Nicholas, J. (1990). *Introduction to descriptive statistics.* Sydney: Mathematics Learning Centre, University of Sydney.

Norusis, M. J. (1990). *SPSS* (Release 4.05 for the Macintosh). Chicago: SPSS Inc.

Roads and Traffic Authority, New South Wales (1992). *How does your car rate in a crash?* Sydney: Roads and Traffic Authority, New South Wales.

Roads and Traffic Authority, New South Wales (1996). *Used car ratings.* Sydney: Roads and Traffic Authority, New South Wales.

Rowntree, D. (1981). *Statistics without tears: A primer for non-mathematicians.* London: Pelican.

Tanur, J., Mosteller, F., Lehmann, E., Link, R., Pieters, R. & Rising. G. (1989). *Statistics: A guide to the unknown.* (3rd ed.). Belmont, CA.: Addison Wesley.

Vygotsky, L. S. (1962). *Thought and language.* Cambridge, Massachusetts: The M.I.T. Press.

Vygotsky, L. S. (1978). *Mind in society.* Cambridge, MA: Harvard University Press.