# *Learning Statistics at a distance*

*Lois Curry*

The Open Polytechnic Working Papers are a series of peer-reviewed academic and professional papers published in order to stimulate discussion and comment. Many Papers are works in progress and feedback is therefore welcomed.

This work may be cited as: Curry, L. *Learning Statistics at a distance,* The Open Polytechnic of New Zealand, Working Paper, December 2002.

Further copies of this paper may be obtained from

The Co-ordinator, Working Papers Advisory Panel
The Open Polytechnic of New Zealand
Private Bag 31 914
Lower Hutt
Email: WorkingPapers@topnz.ac.nz

This paper is also available on The Open Polytechnic of New Zealand website:
http://www.topnz.ac.nz/

Printed and published by The Open Polytechnic of New Zealand, Lower Hutt.



ISSN — 1174 – 4103

ISBN — 0 – 909009 – 55 – 4

Working Paper No: 6-02

A list of Working Papers previously published by The Open Polytechnic is included with this document.

# Abstract

There is evidence from many leading statistics educators that students often find statistics a difficult subject to learn. This is often attributed to the abstract nature of the concepts and, in particular, to the change in thinking required to understand the theory of probability and its application in statistics. For mature-aged students, these difficulties may be compounded by lack of basic mathematical skills and anxiety about learning statistics. In addition, learning at a distance may increase the problems students have in obtaining good understanding of the concepts.

In this paper the current literature relating to learning statistics is discussed, and some findings are presented from a qualitative study that aimed to record the feelings, opinions and experiences of a group of mature-aged students studying statistics in a distance environment. These findings are then discussed with reference to an existing framework described by Belenky, Clinchy, Goldberger and Tarule (1986) for understanding the way women come to know.

The main findings of the study were the following:

- Their lack of mathematical skills was the main reason that students were tentative about tackling a statistics course. Older students and those with little secondary education may have been particularly affected.
- Anxiety was not so extensive as had been reported in overseas studies but is still an issue for statistics educators.
- Almost all students saw value in having a compulsory statistics course in their degree and were aware of the need to interpret data presented to them in their study, work or everyday life.


  

- The mature-aged students demonstrated good metacognitive skills and other learning strategies. Determination to succeed and high motivation were apparent, although many students found the course unexpectedly difficult.
- There was a variety of opinions about the effectiveness of available resources. Support mechanisms were deemed important, as was a face-to-face component in the statistics course and some flexibility in time frames.

# Contents


**Introduction** **1**

Background and objectives 1

Definition of terms 3

**Literature review** **4**

Literature on teaching and learning statistics 4

Literature on teaching and learning mathematics 11

Literature on learning at a distance 13

Literature on adults learning mathematics or statistics 18

**The research** **19**

Methodology 19

Affective issues 20

Statistics education reform — implications for distance learning 24

The learning environment in statistics distance education 28

Women in statistics distance education 32

**Summary** **37**

**Bibliography** **38**


  

# Learning Statistics at a distance

## Introduction

### Background and objectives

Higher education in the 21st century is changing in response to the needs of the population. Increasingly, tertiary students are older and therefore demanding more flexibility in the way education is offered. They no longer have the time or money to sit in a large lecture hall with a few hundred other students. With the rapid technological advances of the last decade, distance education is increasingly becoming the preferred option for many students as it allows flexibility of study times and places and continuity of employment. No longer is distance education regarded as the poor relation of tertiary education. Instead, it is seen as a modern option designed to make full use of technology and to fit in with commitments to job, family and leisure activities.

However, some subjects are seen as fitting more comfortably within this scenario than others. Statistics is one of the subjects that presents special challenges to distance educators.

Statistics has always been a difficult subject to learn. Watts (1991) claimed:

> ...the *major difficulty* that confounds beginning students and inhibits the learning of statistics, and that distinguishes statistics from other disciplines such as mathematics, physics, chemistry, and biology, is that the *important fundamental concepts of statistics are quintessentially abstract*. (p. 290)

Literature from the United States suggests that a compulsory paper in statistics is often viewed with trepidation by students wishing to complete a business or social science degree (Diekhoff, 1996; Gal & Ginsberg, 1994), while in Australia Gordon (1995) found that, overwhelmingly, students studying psychology would not study a statistics paper unless it was compulsory. It is likely that this would also be true of many New Zealand students of business or social sciences. For students who have chosen to complete their degree using a distance education mode, this apprehension may be heightened, since anecdotal evidence suggests that few students would choose to study statistics or mathematics this way, if other options were available. There is a growing body

of literature covering research on the way students learn (or fail to learn) statistics in a traditional university setting. However, there is little empirical evidence of the particular problems perceived by students studying statistics in a distance learning environment.

Consideration of the difficulties faced by students learning statistics has important implications. The way the students perceive and deal with (or fail to deal with) the cognitive and non-cognitive issues is of consequence to those designing distance education statistics courses and is of increasing importance as distance education proliferates with the introduction of on-line learning in many universities throughout the world. Unless these issues are taken into account in the design of distance education statistics courses, learning by distance will simply compound the problems already faced by statistics students in contact institutions.

With the rapid internationalisation of tertiary education, students are no longer restricted to enrolling in a tertiary institution in their country of residence. Universities and other tertiary institutions all over the world are in competition for the tertiary student dollar. With an increasing number of on-line courses on offer, it is apparent that only those institutions that are able to identify and respond to the needs of students will make a success of technologically enhanced education.

This paper discusses some of the results of a qualitative study of mature-aged students studying statistics at The Open Polytechnic of New Zealand. The data was collected by two methods:

- qualitative questionnaires that asked students to describe their feelings and attitudes about various aspects of learning statistics
- semi-structured interviews.

The overall objectives of this research project were two-fold. The first objective was to listen to the voices of students studying an introductory statistics paper in a distance education environment and to determine their perceptions of the value of a statistics course in their degree and their attitudes towards studying statistics. These findings could then be compared with previous research findings on the attitudes and beliefs of students studying statistics in a class environment. The second objective was to record the perceived difficulties, if any, that the students attributed to their choice of the distance mode of education for studying statistics and also to record their strategies and suggestions for overcoming these difficulties.

This paper presents a literature review relating to the learning of statistics and discusses some of the findings with reference to *women's ways of knowing* as described by Belenky et al., (1986).

## Definition of terms

Definitions of the term *distance education* are often complex and have been discussed in detail by Simonson, Smaldino, Albright and Zvacek (2000). Although distance education is generally accepted to mean education where the learner is physically separated from the teacher, tutor or lecturer, the precise definition is subject to debate. In the United States, the term increasingly means education of a highly technological nature, while in the United Kingdom, Australia, Canada and New Zealand, the term has a broader meaning, encompassing a variety of delivery methods, with emphasis on student support.

Within the literature, the term *open learning* is also commonly used. This is a philosophy of learning that recognises variation in learner backgrounds and that has the characteristics of accessibility, flexibility and learner control over content, structure and choice of delivery systems (Paul, 1990). The terms *distance education* and *open learning* are not interchangeable: distance education institutions will have degrees of openness, depending on their individual policies.

For the purposes of this research, distance education is taken to mean education undertaken in the student's home and does not include audiovisual classes where the tutor may be at a distance but the students meet together for instruction. Courses offered by The Open Polytechnic of New Zealand fall mainly within this definition. Distance education in New Zealand is predominantly paper-based, although many courses now have some electronic component, such as listservs, forums or chat rooms, electronic textbooks, interactive learning materials, and so on. The course that was the subject of this project had a set text, a learning guide, an optional video series, an on-line forum and a media activities book, and use of statistical software was an integral part of the course.

Mature age students are defined, for this project, as those students who are not undertaking tertiary education directly after leaving school. Consequently, only students aged 20 years or older were included.

# Literature review

## Literature on teaching and learning statistics

Gunn (1999) has noted that approaches taken in the literature on teaching and learning statistics can be grouped into three partly overlapping areas:

1. *Content and context approach:* This focuses on the goals of the statistics curriculum and appropriate pedagogy but often makes implicit assumptions about how students learn statistics.

2. *Teaching and learning theory approach*: This includes work on how students learn statistics and factors that affect their learning.

3. *Philosophical approach*: This includes discussion of what statistics is, what constitutes statistical thinking and who should teach statistics.

Gunn (1999) argued that there is little work on different ways of knowing (as described by Belenky et al., 1986), cultural dimensions, and theories connecting statistics and education. She also argued that, in approaches to the design and delivery of introductory statistics courses, 'What appears to be missing is a holistic view that simultaneously addresses cognitive, affective and volitional issues' (p. 246).

The following review will encompass current literature in all these areas and discuss how the research has impacted on the teaching of statistics in recent years.

### Affective issues

Consideration of the affective domain (that is, the area relating to emotions, values and attitudes) is an issue for all educators. In a study of undergraduate students Entwistle and Entwistle (1992) noted:

> Students repeatedly commented that the experience of understanding generally had a feeling tone associated with it — there was necessarily an emotional response, at least where significant understanding had been achieved. The inseparability of cognitive and emotional components of understanding was very clear in the comments made by students. (p. 7)

Affective issues such as attitudes, beliefs and emotions are of particular concern to mathematics and statistics teachers. McLeod (1992), in considering these issues in the context of mathematics education, distinguished between these

three categories. He described emotions as fleeting responses, triggered by immediate experiences; attitudes as stable, intense feelings that develop over time; and beliefs as ideas held about the subject and about the individual's ability to learn it. Gal and Ginsberg (1994) claimed that many students were likely to have trouble with statistics owing to non-cognitive factors such as negative attitudes or beliefs regarding statistics. They gave two reasons for the need to address these issues:

1. The issues must be addressed to ensure that a statistics course encourages motivation to learn, confidence in using statistics and a willingness to think statistically.

2. Affective and attitudinal factors impact on the teaching and learning process and may create a learning environment that is not conducive to safe exploration.

They noted that research on students' attitudes was more common than that on students' beliefs, but argued for more research on both aspects.

The most prominent of these affective issues in the statistics education research literature is 'statistics anxiety', which is taken to mean the feelings of worry or panic experienced by students when confronted with the need to complete a course in statistics or when required to collect or analyse data. Statistical anxiety is something that is not specific to any one ethnic group. As Bell (1998) and Onwuegbuzie (1999) have shown, it is common among both international students and African American students studying statistics in the United States.

While statistics anxiety has been discussed in many papers, Roiter and Petocz (1996) claimed there have been 'few definitive studies conducted in this area' (p. 1) and 'Current literature on anxiety does little to provide suggestions that can be easily incorporated into daily practice' (p. 2). Bradstreet (1996), however, noted:

> Simply by asking the students about their concerns at the beginning of a course, and reassuring them throughout a course, a teacher can communicate to the students that he/she is aware of their anxiety and will help them confront and overcome it. (p. 71)

Trying to address the issue of how to deal with statistical anxiety, Townsend, Moore, Tuck and Wilton (1998) showed that using a co-operative learning structure improved students' self-concept but failed to reduce anxiety, suggesting that this is a deeply entrenched emotion and should not be regarded as something that can easily be dealt with.

Predominant among the perceptions students have about learning statistics is their perception of the relationship between mathematics and statistics. Gal and Ginsberg (1994) claimed that students believe that statistics requires quite advanced mathematics and that their experiences of school mathematics may determine the way students approach a statistics course. Bradstreet (1996) also noted, 'The connection between the two subjects (mathematics and statistics) in the minds of nonstatisticians is inescapable' (p. 70).

Gordon (1993) found that students starting a statistics course based their beliefs about statistics on their previous mathematics experiences. Despite their having a reasonable degree of competence in using mathematics in real life situations, 'they expected their university course to be an intimidating, mysterious and difficult subject unrelated to the life skills they had developed' (p. 39). Gordon saw the need to address students' conceptions of mathematics as a first step in providing a suitable environment for enjoyable and successful learning in statistics.

Conceptions of statistics as heavily mathematical means that in the work of Townsend et al. (1998) and others, much of 'statistics anxiety' is thought to be due to 'mathematics anxiety'. Rather than being fearful of doing statistics, many students approach a statistics course feeling anxious about coping with the mathematical aspects. The impact of mathematics anxiety has been discussed by Tobias (1993), who argued that anxiety, not lack of ability, stood in the way of otherwise intelligent adults doing well in mathematics.

### *Cognitive issues*

Among the researchers looking at cognitive issues in studying statistics, Williams (1999) and Gardner and Hudson (1998) have shown that the concepts in a first-year statistics paper are difficult to grasp, and many students end the course with poor conceptual knowledge and an inability to apply what they have been taught. In addition, Konold (1995) and Pfannkuch and Brown (1996), among others, have investigated misconceptions about probability, and within the field of cognitive psychology there is much literature about fallacies based on chance (for example, Fong, Krantz & Nisbett, 1986). Hawkins, Joliffe and Glickman (1992) commented, 'It is probably true to say that the transmission of probability concepts to our students remains our greatest challenge' (p. 60). They argued that this may occur partly because the language of probability differs from everyday language. This may help explain why learning statistics is so difficult. Since probability is such an integral part of the topic of inference, the difficulty in making sense of probability acts as a barrier to the successful learning of statistics.

### *Statistics education reforms*

Over the last decade, there have been calls for substantial changes to the way statistics is taught by universities and other tertiary providers. The changes required were summarised by Hogg (1991), who called for an improvement in the communication skills of teachers, more encouragement for students working in teams on collection and analysis of real data, and more liaison with business, industry and government. The reform movement was discussed by Moore (1997). He linked changes in the teaching of statistics to the development of new learning theories and claimed, 'The central idea of the new pedagogy is the abandonment of an "information transfer" model in favour of a "constructivist" view of learning' (p.124).

In response to reformers' calls for a change in culture from rigour of detail to the teaching of useful applications, he called for a close look at the skills required by employers:

> Note carefully that it is not at all clear that *statistical* skills in the traditional sense are required. Few people will need to interpret ANOVAs, fewer will need to carry them out, and still fewer will need to understand the details behind ANOVA software. (Moore, 1997, p. 124)

For first-year non-statistics majors, Billard (1998) recommended a 'statistics in society' course, engendering an appreciation of statistics, rather than specific methods. Billard saw these courses as reaching future leaders and lawmakers and argued that the courses should be compulsory for all degrees. There have also been calls for teaching statistical reasoning (concepts and thinking) before teaching statistical methods (Bradstreet, 1996; Rossman & Chance, 1999; Wild, 1994). In particular, analysing claims made by media is seen as an important aspect of statistical thinking (Pfannkuch, 1996; Watson, 2000).

Because research (Konold, 1995; Pfannkuch & Brown, 1996) has shown that understanding probability is complex and difficult, Moore (1997) argued for a reduction in the amount of probability taught and advocated covering only the probability essential for inference. Falk and Konold (1992) and others have expressed an opposing view, while Garfield and Ahlgren (1988) advocated the initial separation of probability and statistics teaching. Sharma (1996), in summarising some of the problems relating to definitions of statistics, probability and stochastics, discussed some of the trends in teaching these topics. She noted that there is a growing emphasis on exploratory data analysis in statistical education conferences but claimed that statistics and probability are complementary and an understanding of one increases understanding of the other.

However, the reforms described above may have had less impact than Moore implied, since Garfield (1997), in her comment on Moore's (1997) review, claimed, 'Despite the quality of the available materials and resources and the enthusiasm of education reformers, most statistics courses taught in institutions of higher education have changed very little' (p. 138). She noted that the teaching methods had changed little, the students still expressed anxiety and made negative comments about their class, and the teachers were frustrated by students' poor mathematics backgrounds and their inability to apply their skills.

In an attempt to improve teaching methods, Garfield (1995) provided a summary of research findings, indicating ways of helping students learn statistics:

- small group work
- activity-based courses
- corrective-feedback strategies
- making predictions about the likelihood of samples and comparing with reality
- use of computer simulations
- use of interactive software.

The activity-based courses advocated by Garfield (1995) have been heavily promoted within statistics education over recent years and activity-based tasks have been built into textbooks by Rossman (1996) and Scheaffer, Gnanadesikan, Watkins and Witmer (1996). Garfield (1995), however, noted that there is a need for research to determine what specific activities work best in helping students learn particular concepts. Using such activities in large introductory statistics courses has been a challenge to tertiary teachers (Wild, Triggs & Pfannkuch, 1997), and students do not always perceive the more active approach as desirable. McAlevey and Stent (1999) surveyed undergraduates' perceptions of good teaching in a business statistics course at Otago University and found students preferred a structured approach. Tanur (1997) also noted the preference for a structured approach and asked the question, 'How do we motivate our students to learn actively when they consider it easier to be spoon-fed?' (p. 161). Gal, Ginsberg and Schau (1997) attributed this lack of readiness to embrace an active learning environment to attitudes resulting from prior experiences of mathematics and mathematics teachers.

Snee (1993) has argued that students will better see the value of statistics when it is presented in the context of real life problems. However, McAlevey and Stent (1999) found their students placed a relatively low significance on motivation by way of applications and on relating the application of statistics to relevant business areas. The researchers saw the students' attitude as reinforcing 'the complexity of the task confronting the statistics teacher, who must walk a fine line between selling the relevance of an often misunderstood and difficult subject and successfully imparting the underlying concepts' (p. 225). They suggested that an introductory course may be too early in a student's study for the maximum benefit from using applications to occur.

As a result of the changes outlined above, it became apparent that assessment must change too. Among educators who have addressed this topic are Chance (1997), Garfield (1994) and Hubbard (1997). Chance (1997) discussed the need to assess the students' ability to interpret, evaluate and apply statistical reasoning, rather than merely undertake procedural calculations and noted, 'Assessment should mirror the skills students will need in order to be effective consumers and evaluators of statistical information' (p. 1). Techniques used in her course were a computer laboratory component, a term project with peer reviews and oral presentations, a take-home component of the final examination, minute papers (Mosteller, 1988) and student journals. She argued that these types of assessment were effective not only as instructional and assessment tools but also as motivational tools, thus increasing both learning and retention. Motivation, or lack of it, was also a theme of Hubbard (1997), who argued that many students wish to pass their introductory statistics paper with minimum of effort and therefore focus almost exclusively on assessment. She claimed it was possible to design assessment questions which focused on the goals of the course and distinguished between deep and surface learning as well as motivating the students.

### *Technology in statistics education*

In the last decade, the use of technology in education has expanded rapidly. Bratton (1999) claimed that the impact of technology should be especially strong in the teaching of statistics. He argued that, as the computer is an essential tool for a practising statistician, students should be taught to use computers to reduce tedious calculations, to enable use of more realistic data sets and scenarios, to run appropriate simulations, and to obtain more precise results. Such a learning environment would 'focus on developing fundamental statistical concepts' (p. 2).

As well as the statistics software packages that are available to students, there are a number of programs designed to teach statistics at an introductory level (Ganesh & Ganesalingham, 1998). Computers, graphics and videos now have the potential to demonstrate the use of statistics in ways undreamt of in the past and to assist teachers in innovative presentation. However, Ferris and Hardaway (1994) claimed that the rate of change in teaching is much slower than the rate of change in technology and commented:

> Technology by itself will not solve educational problems; rather the intelligent and creative development of a multimedia approach may provide an alternative method or a supplement for the more effective teaching of statistics. (p. 5)

Despite the development of technologies, Moore (1997) saw an important role for the teacher, especially as motivator, encourager and assessor, and claimed that emphasis on multimedia technology neglected the social aspect of learning and the personal presence. The need for a personal approach is evident in the research of Schuyten and Dekeyser (1998), who noted that students preferred to learn statistics in the traditional lecture format rather than independently in either electronic or paper mode. Bradstreet (1996) also emphasised the need for a very good relationship between the teacher and the students, noting that without such a relationship, no amount of resource material will produce a good outcome for the students. However, McAlevey and Stent's (1999) Otago University students gave 'establishing positive relationships with students' a low ranking when asked about the main task of a statistics teacher.

### *Statistics and distance education*

Within the literature on learning statistics, there is very little discussion on distance education as it is known in New Zealand. At the most recent International Conference on the Teaching of Statistics, Lunn (1998) discussed the development of statistics courses offered by the Open University and noted that although the technological advances in other institutions were exciting, educators must not lose sight of the needs of developing countries where computer access is limited. At the same conference, Dunning and Lai (1998) examined the use of a mailing list and a telephone help desk for students studying an introductory business statistics paper at Massey University. They saw the need for further research and development to encourage their use and provide extra benefits for students learning at a distance.

Although there is much written about interactive software for the teaching of statistics, most of this software is being developed to be used in conjunction with face-to-face lectures, tutorials and computer laboratory sessions. However, there are obvious applications within a distance learning environment, and

there is some evidence that a totally computer-based course with interactive software will be well accepted by distance learners (Martens, Valcke, Portier, Weges & Poelmans, 1997). It is yet to be determined whether this will provide the best outcomes for students, and Phillips, Francis and Hutcheson (1998) noted that technology can be used to enhance statistics courses but will not necessarily replace traditional delivery modes. They advocated a multimodal approach to overcome the disadvantages of any one method and to provide students with a choice to suit their preferences and learning styles.

## Literature on teaching and learning mathematics

The discussion of affective issues in the teaching of statistics has shown that there is a close link between mathematics and statistics in the minds of students and the general public. Therefore, it will be useful to look at some of the research literature relating to the learning of mathematics, particularly that relating to affective, motivational and metacognitive issues.

### Affective issues

McLeod (1992) reviewed the research on affect in mathematics education and noted that most of the research had not been grounded in a strong theoretical foundation. He saw the need for researchers with an affective orientation to work more closely with those having a cognitive orientation and noted that although there had been much research in this area, it had not had a major impact on the way mathematics was taught.

Within the broad topic of affective issues, mathematics anxiety has been the subject of a considerable amount of research. In an attempt to quantify the impact of mathematics anxiety, Ho et al. (2000) undertook a study based in three different countries. They found that anxiety had a negative relationship to mathematics achievement and claimed that this could negatively impact on mathematics-related activities such as learning statistics. They made the distinction between the affective and cognitive dimensions of mathematics anxiety, finding that affective anxiety was more detrimental to performance. This negative relationship has been confirmed by the meta-analysis of Ma (1999), who found that the relationship was consistent across gender groups, grades, ethnic groups, instruments measuring anxiety, and years of publication.

Several researchers have designed and evaluated courses that attempt to address the impact of affective issues on mathematics students. Fiore (1999) discussed how mathematics anxiety could result from bad experiences within mathematics classrooms and referred to students affected in this way as 'maths-abused' students. He noted, 'Preventing and overcoming math anxiety begins with teachers and teaching strategies that develop positive and realistic self-concepts' (p. 4). For older students who have previously experienced failure in mathematics, innovative teaching approaches using dialogue, reflection, personal relevance and a more supportive environment have been shown to be successful (Burton, 1987; Patrick, 1999). Patrick found that as her course progressed, her students' attitudes to mathematics changed, as did their recognition of existing skills and knowledge, and, 'Increased confidence was the main ingredient needed to enable them to learn mathematics' (p. 95).

Within the tertiary sector, Anthony (2000) has shown that students ranked 'self motivation' as the factor having the most important influence on success in a first-year undergraduate mathematics course. This was followed by 'study for tests and exams' and 'making sure the basics are understood'. These results were compared with lecturers' perceptions of factors, as it was recognised that both teaching and learning processes influence the learning outcomes. Lecturers agreed that motivation was the most important factor. Crawford, Gordon, Nicholas and Prosser (1998) researched how students' prior understanding of the nature of mathematics related to their perceptions of learning contexts, approaches to study and learning outcomes. This study extended their previous research (Crawford et al., 1994), which showed that most students entering university regarded mathematics as a fragmented body of knowledge and used repetitive and surface approaches to learning that were related to the ways that they conceived mathematics. These researchers identified two distinct patterns in their 1998 study: they found that

- *fragmented* conceptions of mathematics were associated with surface approaches to learning mathematics, perceptions of assessment as measuring reproduction, and perceptions that the workload was too high.

- *cohesive* conceptions of mathematics were associated with deep approaches to learning mathematics, perceptions of good teaching, and clear goals.

They urged a more systemic view of the learning environment with more awareness of students' total experiences of learning mathematics.

### Metacognition

Metacognition in mathematics learning has been considered by Goos and Galbraith (1996), Wilson (1998), and others. Metacognitive processes are thought to be crucial for effective mathematical thinking. Wilson (1998) reviewed previous literature that attempted to define metacognition (the term first used by Flavell, 1976) and noted that it referred to both knowledge about cognition and regulation of cognition. She concluded, 'Metacognition refers to the awareness individuals have of their own thinking and their ability to evaluate and regulate their own thinking' (p. 694) but noted that existing definitions are imprecise and difficult to interpret in operational terms. She claimed that suggestions of a link between metacognition and the ability to solve mathematics problems meant that assessment practices in mathematics should include assessment of student metacognitive thinking so that students have the opportunity to develop these ideas.

In Anthony's (2000) investigation into factors influencing first-year students' success in mathematics, questionnaire responses showed lecturers placed less importance than students on active attention in lectures and note-taking, indicating that lecturers see the need for reflection and self-directed learning after the lecture. However, in contrast to the student questionnaire responses, interviews with students showed little evidence of active learning in lectures. Anthony suggests that not all first-year students have the effective metacognitive strategies to be independent learners.

## Literature on learning at a distance

### Constructivism in distance education

The reform movement within statistics has been based largely on a social constructivist approach to learning, whereby learners actively construct their own meanings, building on their prior experiences and knowledge, the teacher taking on the role of guide and motivator. Within the literature, there has been much debate over whether this style of learning and teaching can be adequately delivered by distance educators. Beaudoin (1990) argued that there are essentially two views of distance education:

1. as prescriptive and creating dependency
2. as promoting autonomy and encouraging self-directed learning.

Constructivism within a distance-learning environment has been considered by Garrison (1993), Jonassen, Davidson, Collins, Campbell and Bannan Haag (1995), Kember (1994), and Young and Marks-Maran (1998), among others. Kanuka and Anderson (1998) claimed that social constructivism is 'currently the most accepted epistemological position associated with on-line learning' (p. 60). Jonassen et al. (1995) argued that a constructivist approach can work well in distance education settings when supported by a variety of computer-mediated communication technologies. However, they also noted, 'Too often, potentially interactive technologies are used to present one-way lectures to students in remote locations' (p. 7).

There are two features of a social constructivist approach to teaching that may be problematic to both distance educators and students alike. Firstly, an integral component of this approach is the use of small group activities. These develop communication, team-building and interpersonal skills, much valued in today's workforce, and enhance students' deep learning as they negotiate a shared understanding with their peers (McAlpine, 2000). In the past, this process has been difficult for students learning at a distance to practise. However, with advances in computer-mediated communications (CMCs), it is now possible for geographically dispersed students to work in groups (for example, Seaton, 1993; Stacey, 1999). Small group work within statistics has been widely promoted by, among others, Bradstreet (1996), Garfield (1995) and Moore (1997). It is thought to provide good training for professional careers where communication and team work to solve problems are considered important.

Second, and closely related, a social constructivist approach to teaching encourages articulation of problems and solutions (de Corte, 1995). Garrison and Shale (1990) noted, 'Improving the quality of the educational process through increased two-way communication is likely to have the most significant impact upon the effectiveness of learning' (p. 128). Advances in technology such as Web-based chat groups now allow distance students to communicate with each other and to develop a 'community of learners'. Such mechanisms can allow discussion on aspects of the course being studied in keeping with a social constructivist approach but may be more effective for senior students: 'Students who are cognitively immature are not as likely to be active participants in CMC learning situations' (Seaton, 1993, p. 51). They may also be more applicable for some subject areas than for others. It is also debatable whether communication by electronic means can ever obtain the interaction that proponents of constructivist teaching initially visualised. Computer-mediated communications are quite different from face-to-face communications because the body language element is missing. It should also

be noted that Burge and Haughey (1993), Garrison, Anderson and Archer (2001), Kanuka and Anderson (1998) and Maher (1998) all argued that the implications for learning using technologically enhanced communication means are not fully understood.

### *Metacognition and affective issues in distance education*

Metacognition 'is thought to be an important factor in the acquisition of higher order intellectual skills such as problem solving, decision making and critical thinking'. (Young & Marks-Maran, 1998, p. 31) and is therefore an important issue in statistics education. White (1999) studied metacognitive issues among distance learners of languages and found marked diversity in the metacognitive knowledge of students. In this learning context, 'affect emerged as an integral component of metacognitive knowledge and experiences, and the ability to control and harness affective reactions was identified by students as critical for success' (p37). In a previous study, White (1997) found that distance students reported much greater use of metacognitive strategies than classroom learners, especially with regard to self-management, advance organisation and revision. White concluded from these studies:

> There is a role for orienting students to distance learning in terms of fostering their understanding of the process: in particular it is important that they recognise that the development of metacognitive knowledge is recognised as an integral part of the experience of most distance learners. (White, 1999, p. 44)

Studies of affective issues among distance students have shown high levels of anxiety, which may impede their learning (Jegede & Kirkwood, 1994). In their study of distance students at The University of Southern Queensland, Jegede and Kirkwood found that content of study materials, finance and readiness were the top three factors perceived as affecting students' learning at a distance. It is also noteworthy that they found that the variables of age, marital status and course of study were significantly related to students' opinions about studying at a distance but not significantly related to students' anxiety. However, relatively small numbers (222 students completed pre- and post-semester questionnaires) may have obscured any differences in anxiety attributable to the course of study, such as mathematics or statistics. Jegede and Kirkwood saw the need to continue research into the effect of anxiety and factors that affect learning at a distance, to determine the role these issues have in attrition rates.

While computers are most commonly used for communication between students, or between students and tutors, they are increasingly being used to deliver whole courses on-line. As they have done with technologically enhanced communication, many educators have questioned the amount known

about the pedagogical basis on which these courses depend (for example, Reeves & Reeves, 1997). Research has shown that the benefits include convenience, increased motivation, access to current and global information, and increased understanding through interactive and virtual reality features, while barriers can include lack of appropriate software and lack of technical support for both students and teachers (Daugherty & Funke, 1998). Technological issues such as speed, cost and access need to be considered in conjunction with pedagogical issues such as choice of medium, amount of information and degree of overall cohesiveness (Hill, 1997).

Chen's (1997) evaluation of five technological distance delivery systems considered four pedagogical issues:

1. interaction between students and teachers
2. instructional strategies
3. motivation
4. feedback/evaluation.

Chen argued that the instructional implications of the delivery systems should be considered carefully before they were selected for a course and concluded, 'The strengths of distance education reside in the appropriate selection and choice of a precise mix of distance technologies' (p. 37).

### *Women in distance education*

Among the literature on student support there is some evidence that support for women students may need to be different from that for men. Despite May's (1994) contention: 'It is crucial to consider the feminist ramifications of distance education in order to enhance understanding of women distance learners' (p. 82), the published literature relating feminist theory to an analysis of women studying at a distance is a relatively recent development. Burge (1988a) noted, 'While talk about women distance learners and educators has been plentiful, writing and research has not' (p. xi), and since then the literature has been sporadic. Burge and Lenskyj (1990), Coulter (1989), Grace (1991), Hipp (1997), Kirkup and von Prummer (1990), and May (1994) have all looked at women's experiences as distance learners. May (1994) claimed that distance education was experienced differently by men and women and Kirkup and von Prummer (1990) showed that women learners' preferences are often for collaborative and connected experiences. This last piece of research threw doubt on the previously common view that distance learning was particularly suited to

women who are predominantly responsible for household management and childcare (Kirkup, 1996). It also, more recently, gave support to the notion that computer-mediated communications would have particular benefits to women students. This, however, may not be the case. Although May (1993) argued that collaboration in education was a fundamental feminist principle, her research showed that some women students had reservations about the value of increased collaboration (by phone or teleconference): 'Group interaction was considered an impediment to the extent that it was thought to be superfluous, to slow down individual study progress, and to inhibit personal experience' (p. 42). May concluded that busy women need to be persuaded of the benefits of collaborative learning, while institutions need to support a variety of collaborative activities.

Hipp (1997) looked at the support services women distance students needed and concluded from surveys and interviews that the main concerns related to confidence, overcoming isolation and connected teaching. The idea of connectedness in knowing arose from the work of Belenky et al. (1986), whose book *Women's Ways of Knowing: The Development of Self, Voice and Mind* explores the way women view reality and draw conclusions about truth, knowledge and authority. Their findings were based on extensive interviews with 135 women of different ages, ethnicity and backgrounds. Their model groups the women's perspectives into the five categories of

- silence
- received knowledge
- subjective knowledge
- procedural knowledge
- constructed knowledge.

*Connected knowing* was a name given to one of the two types of procedural knowing and is in contrast to *separate knowing*. A connected knower builds on personal experiences and questions the circumstances that lead to a perception of knowing. This theory has been useful in understanding women's alienation from some subjects and their different styles of communication (Kirkup, 1996). Over recent years, implications of this work have been discussed in relation to learning mathematics (Becker, 1995; Erchick, 1996; Ocean, 1998), but as yet not in relation to learning statistics (Gunn, 1999). Ocean (1998) claimed, 'A Connected Knowing approach to mathematics is concept-based and creative, and places the emphasis on co-operation rather than competition' (p. 428).

Another issue for women students is the increased use of technology. O'Rourke (1999) considered women's experiences of learning technology in relation to issues such as access, affordability, trust and privacy and the value of social and co-operative learning. She urged caution in the development of new technologies:

> Gains made by distance educators and feminist educators in enabling more holistic experiential approaches to learning could be threatened if new technologies preclude that which cannot be easily transmitted in a crisp comment in an electronic conference, or presented on a web page. (p. 107)

In particular she noted the tendency for institutions to cut back on student support in times of economic tightening, but to continue to invest in new technology.

## Literature on adults learning mathematics or statistics

Finally, there is a small amount of literature on mature-aged students learning of statistics or mathematics. Leder and Forgasz (1998) found that fewer mature-aged students than school leavers were studying mathematics because they believed they were good at it. They found that mature-aged students rated university mathematics as more enjoyable, challenging, interesting and well taught than school leavers did and also that they attributed likely success to hard work. Surprisingly, they found no differences in perceived levels of competence with computers or calculators.

Only one paper relating to mature-aged students' study of statistics has been found. Gordon (1993) has explored the approaches to learning of a small group of mature students studying statistics from an activity theory perspective. Her interview data showed a range of beliefs about mathematics and a range of perceptions of the learning context, and she claimed that the students' awareness of the meaning of their own experiences and environment was at the core of their learning. In relating the findings to improving the teaching of statistics, she suggested that the role of the teacher is to guide students to view their learning as relevant and meaningful rather than to transfer a body of knowledge. To do this effectively, 'the implicit assumptions underlying the content, presentation and evaluation of the course need to be examined in the light of the students' perceptions' (p. 45). She concluded, 'In short, in order to negotiate a shared view of statistics with the learners, the educator needs first to understand the nature of the activities, mediated by personal and reflective aspects, in which the learners are engaged' (p. 45).

# The research

## Methodology

There is support in the literature previously reviewed for a qualitative approach to understanding the way students learn statistics. Among the distance education literature, Evans (1994) noted that support services for students should be driven by students' individual needs: 'The challenge is to develop and maintain approaches which enable students to have their voices heard and for the open and distance educators and their institutions to be able to listen and understand the practical implications of what is being said' (p. 128). Burge (1988b) also noted:

> If the production of knowledge about distance learners, learning processes and tutoring strategies is to develop beyond experimental methods, it will do so through the greater use of methods that focus on how learners perceive and interpret their realities. (p. 7)

Similarly, but from a feminist point of view, Hipp (1997) argued, 'In order to ascertain the sorts of education and support appropriate to women's needs it is necessary to understand and know more about their experiences' (p. 48).

There is also support for qualitative research in the literature on learning statistics. For example, Gal and Ginsberg (1994) reviewed two surveys designed to assess attitudes towards statistics: the 'Statistics Attitude Survey' (Roberts & Bilderback, 1980) and the 'Attitudes Towards Statistics' survey (Wise, 1985). While they noted the need for statistics educators to be able to assess students' attitudes and beliefs, they concluded that the current assessment instruments, which use Likert-type scales, reveal little useful information:

> Especially when it comes to mathematics or statistical anxiety, which may negatively influence students' interest, motivation, and comprehension, it appears that Likert-type scales have very limited usefulness for identifying what individual students are anxious about, their beliefs about learning statistics that might be counter-productive, and what types of support or educational experiences might be useful for students. (Gal & Ginsberg, 1994, p. 9)

They saw the need for inclusion of open-ended questions, structured interviews or focus group discussions to provide better understanding of the factors affecting learning.

The most prominent qualitative research in the statistical education field is Gordon's (1993, 1996) research on students studying statistics at the University of Sydney:

> The use of a phenomenographic approach to this research has allowed us to describe the experience of learning statistics at university from the point of view of the students themselves. We have attempted to give our students a voice, a voice not normally heard in statistical education. (Gordon, Nicholas & Crawford, 1996, p. 12)

With these comments in mind, a qualitative approach was selected, as the researcher sought to understand the experience of learning statistics at a distance from the perspective of the learner.

The data was collected by two methods, questionnaires containing open-ended questions, which were sent at the beginning and at the end of the semester, and interviews.

All qualifying students enrolled in the course were sent the questionnaires. These students appeared to be spread throughout New Zealand in a manner representative of the country's population distribution. Sixty-five beginning and 42 ending questionnaires were received, giving response rates of 55 to 60 per cent.

Eight students were selected for interviews from among willing candidates. Those selected were chosen to represent both men and women, a variety of ages, and a mix of experienced and inexperienced distance students.

Ethical approval was granted by two ethics committees. At all times the privacy of the students was respected, and they were fully informed of the purpose of the interviews and the way their comments were to be used.

## Affective issues

In response to the request that students write down how they were feeling about starting their statistics course, over one third of the women respondents used the word 'apprehensive'. The words 'daunted', 'overwhelmed' or 'stressed' were also mentioned by both men and women. Some students were already saying the course was beyond their capabilities. On the positive side, about one quarter of all students made positive comments, using words like 'excited', 'keen' or 'looking forward to it'. One student was *'keen to start, keen to finish*'.

By far the most common reason for feeling apprehensive or worried was the mathematics background of the students. Many cited the number of years since they studied any mathematics. A typical comment was:

> *I last studied mathematics nearly 30 years ago — we didn't even use calculators for stage one then!*

For many students, memories of mathematics from school years are obviously focused on formulas and equations. These were mentioned several times:

> *Seems daunting, having to remember the mathematical equations.*

On completion of the course, mathematics was also often mentioned; for example:

> *It is a very maths-oriented subject — I found it difficult.*

> *I'd not had a lot of experience of stats and my maths wasn't strong, so the course seemed difficult prior to even starting.*

Many students were unable to identify specific areas of mathematics that caused them problems. Instead, the apprehension seemed to be due to the mystique that mathematics and related topics hold in society in general. Mathematics has always been a school subject with a limited following, and it is currently acceptable, even commendable, for otherwise accomplished adults to admit that they have never been good at mathematics. The poor mathematics backgrounds of students attempting a first-year statistics paper have long been a concern for many statistics educators. For those offering a paper by distance education the problem is accentuated. Firstly, the majority of students learning this way are older, and therefore it is often many years since the students have done any mathematics. Secondly, and also because of their age, many learnt mathematics at a time when memorisation of formulae and rigour of proof were the norm in teaching mathematics. For many of these students, memories of their mathematical classes were not favourable. Thirdly, an open-entry policy for students at The Open Polytechnic of New Zealand means that a significant number of students have limited secondary education.

To compare the feelings of this group of students with the feeling of students from overseas studies, evidence was sought to support or reject the statement: 'The common denominator of students beginning their study of statistics is dread' (Diekhoff, 1996, p. xv). In responses from students at The Open Polytechnic, there were enough positive comments to suggest that the majority did not feel this way. Certainly there was apprehension and anxiety, but this seemed to be due mainly to doubt about mathematical skills. If this could be

addressed, there is reason to believe that most students would enter their statistics course with enthusiasm and optimism. Most of the comments referring to a common dislike of statistics courses emanate from the United States, and there is little evidence to support these claims from this group of students. It could be that because New Zealand schools have a relatively long history of teaching statistics, students see the subject in a more positive light than their American counterparts.

There was undoubtedly some anxiety shown by students, not only because of mathematics but also because of the novelty of the concepts. Gal and Ginsberg (1994) noted that statistical anxiety may affect the interest, motivation or comprehension of students, so it is important that these issues are acknowledged. Also, Roiter and Petocz (1996) argued, 'The affective domain of learning is sometimes left to chance, but recognising and addressing concerns about anxiety seems to be a vital initial step in the design of introductory statistics courses' (p. 1).

Questions relating to confidence in the students' ability to complete the course revealed a clear gender difference: the men felt more confident than the women. Almost all of the men were confident of successfully passing the course, with such comments as

> *Failing is not an option.*

The women were much more tentative about their abilities, with several not at all confident of passing and others feeling only moderately confident. Some, however, showed determination:

> *I am determined to complete this course and have arranged my life around achieving this.*

Overall, the findings relating to the confidence of the students contradicted those of Townsend et al. (1998), who reported that 64 per cent of second-year educational psychology students surveyed at the University of Auckland said that they did not feel confident at the beginning of their course. In this study, the proportion was much lower, with only about 15 per cent saying they were not confident or only moderately confident. From the interviews with students, and also from the questionnaire results, a clear determination of many of the students to succeed was apparent. Some students rearranged parts of their lives:

> *I gave up my job and had four-week's slog before the exam.*

In all distance education courses, a certain percentage of students fail to complete. Previous research has shown that distance education students drop out for a variety of reasons:

- outside influences such as lack of time, family crises, and so on
- student attributes such as insufficient motivation, perseverance, or academic ability
- factors that relate to the institution (Grote, 2000).

Some students in the course, however, had an impressive academic record but seemed unable to cope with a statistics course, despite continued efforts by the tutors to provide help and support.

Although they had initial reservations, most completing students were positive about the value of the course and words like 'achievement' and 'interesting' were commonly used. Typical comments were:

> *I actually enjoyed the course and it made me interested in statistics — just wish I had time to do it justice.*
>
> *Statistics was quite alien to me when I began and some of the concepts very hard to grasp. Now I feel as though I have really achieved something that I was anxious about and I am proud of that achievement.*
>
> *I can't think of a degree where you would want to walk away having finished it and know nothing about statistics. I think it has real value as it can make sense of a lot of real life situations and aid understanding of those situations.*

Several students, although giving a positive response, qualified it with a comment to the effect that they had found it difficult or that it had been very time-consuming.

Despite this apparent appreciation for the real life value of the course, most of the interviewed students said they would have been unlikely to choose the paper had it been optional. This is in keeping with Gordon's (1995) findings that 73 per cent of her psychology students would not have chosen to do a statistics paper. This presents a paradox: a subject that is seen as important to a degree but not one that students want to do.

One reason for this paradox was discussed by Morrow (1996) with reference to gender issues in learning mathematics. She claimed that educators and parents passed on this erroneous idea:

> Literature and social science are richly connected to human concerns and creativity while mathematics is removed and mechanical. The task that lies ahead for all of us is to help women see that not only can they do mathematics, but it is an area through which they can become *connected to* people rather than *disconnected from* others. (p. 14)

The same perceptions apply to learning statistics, as articulated by one interviewed student:

> *I wouldn't have chosen it as my preference is for more people-oriented stuff.*

## Statistics education reform — implications for distance learning

As discussed previously, there have been changes over the last decade in the way statistics is taught. Proponents of these changes called for more emphasis on statistical thinking, more use of real data, less emphasis on probability theory and formal derivations, and encouragement of active learning by means of group activities, oral and written presentations and projects (Moore, 1997). While there is still debate over the learning outcomes, course content and style of assessment that would best suit students who are likely to ever do only one statistics course, there is little debate over the overall objective of such courses: 'A major concern of those who teach statistics is how to ensure that the students understand statistical ideas and are able to apply what they learn to real-world situations' (Garfield, 1995, p. 25).

The course discussed in this project follows a relatively modern format, with less emphasis on probability theory and more emphasis on data production and data exploration. The direction of the course is determined by the order of topics in the textbook, and it was clear that most of the interviewed students followed the suggested timetable quite closely.

The integral use of software in the course is intended to help students learn basic concepts. However, it appears that given the time constraints, most students used it solely as a substitute for manual calculations and to meet the assessment requirements. The limited use made of the optional interactive computer activities showed that few students were able to take full advantage of the possibilities they offered. It is not known whether this was due to the design of these resources or because their use deviated from the structured approach of the course shown to be preferred by many students doing a first

course in statistics (McAlevey & Stent, 1999; Tanur, 1997). Ideally, software should be used to enable students to explore the data more fully by displaying it in different ways, simulating and analysing it under different assumptions. Attention needs to be focused on how distance educators can encourage students to participate in this way.

Even with the use of computer software to complete long calculations, students saw statistics as a very mathematical subject. Indeed it is clear that some mathematics understanding is vital. Gordon (1993) noted:

> The learning of statistics necessitates deep and surface approaches executed in a complementary, rather than contradictory, manner to take into account two distinct and identifiable aspects of studying it. One aspect, dealing with the algorithmic component, involves the process of recognising, applying and remembering mathematical techniques and skills. The other comprises an interpretative component and entails analysing the problem, inferring a suitable technique for solving it, and clarifying the result. (p. 36)

It is apparent that some students, probably those with the weakest backgrounds in mathematics, never get beyond worrying about the calculations. This barrier is preventing them from getting an overview of what statistics is all about. It is possible that, by allowing students to enter the course without any formal mathematics education, a disservice is being done to both students and teachers.

It is clear to statistics educators that statistics has its own set of concepts, quite unrelated to those in pure mathematics and often quite foreign to students. Clayson (1998) commented, 'We forget, I think, just how weird statistics is to most undergraduates, certainly to the non-science ones' (p. 1077). Teachers must find innovative ways of presenting the concepts, while recognising the difficulty many students have in grasping them.

One innovative way was advocated by Garfield (1995), who suggested having students confront their own misconceptions about statistical ideas, especially about chance events. She also noted that teachers often overestimate how well their students understand basic concepts, a point commented on by a student completing this course:

> *Tutors rushed through the steps thinking it was easy for everyone to understand.*

Predominant among the general principles of learning statistics that Garfield (1995) lists is the active involvement of students in learning activities. Garfield argues that research shows that students learn better if they work co-operatively in small groups, which provides opportunities for students to express their ideas both orally and in writing. In distance education this is

difficult. Even with new technologies, the use of small groups of distance education students working together is likely to be far less successful than in a face-to-face environment. Also, the opportunity for this type of interaction within a first-year statistics course may be limited by students' experience and skill base. Carr-Chellman, Dyer and Breman (2000) found:

> It is possible to enact authentic learning and distance collaboration within modified distance education when learners are advanced in their studies, have had previous experiences collaborating at a distance with smaller projects, and are prepared for the challenge of authentic experiences by seeing strong relevance to their own work. (p. 39)

Commenting on the above piece of research, Henri and Haughey (2000) claimed, 'Collaboration is one of the most challenging human activities. It banks on abilities that are not innate; it has to be learned' (p. ii).

It was apparent that even using the on-line forum was daunting for some students, so it may be that expecting first-year students who don't know one another to co-operate on a project would be short-sighted. One student noted:

> *I read others' messages but did not join in. I believe it could be used far more for discussion but still seem reluctant to join in.*

Nevertheless, active learning by engagement of distance education students with their study is still possible. Hands-on activities, computer simulations, and so on are possible for distance students and activity-based courses are available. Consideration could be given to incorporating more of these into the course design, especially as part of the assessment process.

In conjunction with the changes to the course content and style of delivery of statistics courses, has come a call for changes to the assessment process. Since there will always be some students who will do only what is required to pass the course, Hubbard (1997) noted that assessment 'can be used as a powerful tool to encourage students to adopt deeper rather than surface learning strategies' (p. 1). The assessment for the course studied in this project consists of two assessment tests, an examination and a project for which students collect data themselves and choose appropriate analysis. The assessments seem to have been well received:

> *The assessments were really good for firstly making sure you understand the work and secondly, making it applicable and thirdly, seeing its relevance.*

The project, while encouraging students to use data they were interested in, met with a mixed response:

> *The project was wonderful — it took me a while to decide what to do, but once I was away, it was excellent. I really enjoyed it.*
>
> *I felt we didn't have enough statistics information to manipulate the data in order to do the work.*
>
> *Doing the project helped, especially relating to chi-square tests.*

Hogg (1991) noted:

> Projects give students experience in asking questions, defining problems, formulating hypotheses and operational definitions, designing experiments or surveys, collecting data and dealing with measurement error, summarising data, analysing data, communicating findings, and planning 'follow-up' experiments suggested by the findings. (p. 342)

While not all of these aspects of a project are expected for the course under discussion, the project still gives students a chance to experience the difficulties in gathering data and the opportunity to practise their statistical communication skills. While an oral, or video-taped, presentation is permissible, no students have taken up this option. Within distance education, oral presentation skills are more difficult to encourage and assess.

It is possible that the project could be better managed by allowing the assessment to be done in several phases, with feedback after each phase. A longer time period would be needed to accomplish this, so consideration could be given to eliminating the examination. The idea of an examination as a fair means of assessment for adult students is subject to debate:

> Formal examinations mean that mature students are given only the same time as those aged 18–22 years in which to recall the salient points on a topic, as well as to use them in a constructive logical way in a response. There would seem to be a great deal of evidence, even if retrospective, that such exams are not a suitable or fair means of measuring the performance of mature adults. (Sutherland, 1997, p. 199)

One student commented on this:

> *An exam, based on memory skills, should not be the sole decider on whether or not that course is passed.*

Even in its current format, the time over which the course is run needs further consideration. Several students mentioned lack of time to understand concepts and reflect on their learning:

> *You vaguely learnt something then had to move on to something else. I didn't feel all that confident through much of the course that I had absorbed it as well as I should have and that was because it was so rushed.*
>
> *New concepts took a long time to understand and fit into the scheme of things. Why, where and when are those concepts used?*
>
> *We were motoring through the textbook at breakneck speed - no time for contemplation.*

Parker, Pettijohn and Keillor (1999) also noted this: 'A limited resource in the introductory statistics course is almost always time; there are too many critical subjects to discuss and too little time' (p. 4).

For distance education students, most of whom are working and raising families, the time frame over which a statistics course is offered needs serious consideration. If we expect our students to meet the previously stated objective of understanding of statistical ideas and being able to apply them, then an appropriate time-frame must be negotiated.

## The learning environment in statistics distance education

Moore (1997) claimed that the current reforms in statistics education are based on a constructivist view of learning. Previously, the literature relating to constructivism in distance education was discussed, and it was noted that depending on the point of view of the commentator, traditional distance learning can be said to be based on either a constructivist theory or an 'information transfer' (behaviourist) model.

Several leading statistics educators (Moore, 1997; Chance, 1997) are advocating spending less time in lectures and more in a variety of other learning and assessment tasks. Chance (1997) commented:

> I think it is important for the students to learn to identify the components of an effective statistical analysis or explanation for themselves. I want students to do much of the discovery for themselves, because what students construct for themselves they will understand better and remember longer. (p. 7)

Since distance education students do spend more time on activities such as making their own notes, working through examples, and so on, and rely on their own cognitive efforts to gain a grasp of a subject, it can be argued that they

are actively constructing knowledge. However, active learning, as advocated in constructivist learning theory, will not necessarily happen in a distance environment any more than it will necessarily happen in a classroom or university setting. Distance students, if they have the time and interest, can certainly learn this way. With adequate resources supplied by the institution, a variety of interactive and meaningful activities can lead students through this process. Assessment tasks can be better designed to measure the degree to which students demonstrate a deep understanding, and increased research can provide empirical evidence of such learning.

However, two other important characteristics of effective learning that must also be considered are motivation and metacognition (Young & Marks-Maran, 1998). In contrast to first-year mathematics students (Anthony, 2000), many of whom appeared not to have the metacognitive strategies required for independent learning, the older age and greater life experience of Open Polytechnic students might stand them in good stead for this type of learning. Indeed, Moore (1997) claimed, with reference to learning statistics, 'Distance learning has proved effective for mature and motivated students; it works much less well for relatively immature and less motivated students we often see in first courses' (p. 134). In keeping with the findings of White (1997), there was certainly much evidence of both self-knowledge of cognition and self-regulation of cognition in this group of distance students:

> *I am a visual learner.*
>
> *I'm going to set myself goals and keep focused on the target dates.*

Further evidence of the advanced metacognitive strategies employed by these students was obtained from the responses given when the interviewed students were asked what advice they would give to students about to start this paper. Student responses also indicated high awareness of a range of help-seeking and revision strategies. The following responses were obtained:

> *Ask around your networks and see who might be able to help if you get stuck.*
>
> *Don't get too flustered if you don't understand everything at first — it will slowly sink in. Keep at it. Do a little every day rather than a big session once a week.*
>
> *Be well organised, manage your time well. Do lots of practice exercises.*
>
> *If you are concerned about your maths, revise first. Use the exercises in the Study Guide and the Tutorial Notes.*
>
> *Don't panic, have a strict routine, allow plenty of time, be determined.*

*Go to the tutorial, use the on-line forum, if you get stuck contact your tutor.*

*Try to apply it — look at real life situations. Persevere — that's the main thing.*

Many of the students were also highly motivated, despite reservations about their ability in mathematics. A typical comment from a beginning student was:

*I'm determined to finish, and excited, but also apprehensive and slightly stressed.*

Taylor (1996) suggested that two important features of successful learning were the ability of students to co-ordinate metacognitive strategies with their goals; and the ability of students to be flexible in their approaches to learning, so they could tailor their approach to the demands of the particular learning environment. Placing high value on the learning of statistics, being motivated to succeed, albeit with reservations about mathematical ability, and demonstrating good knowledge of metacognitive strategies appear to be characteristics of many successful students in this course.

However, to some extent, students' ability to adopt a deep approach to learning may have been hampered by lack of active learning materials, too short a time frame and a rigid assessment programme.

Current learning theories, such as social constructivism, give a central role to language in an effective learning environment. Social constructivism 'assumes that language is used for negotiation of meaning and conceptual delimitations' (Kanuka & Anderson, 1998, p. 66). The lack of opportunity for group activities, as described in the previous section, is a major problem for distance educators. As discussed previously, research findings make it unlikely that computer technologies will enable beginning students, who rarely know another member of the class, to effectively work together on statistics projects in the near future. Even if students were able to work together, they would need to agree on a suitable project topic, which would eliminate the advocated practice of using data that is personally relevant to each student.

Similarly, there is little opportunity in distance education for oral discussion and presentation, although on-line forums and chat rooms do allow students to discuss problems electronically. The use of these methods to discuss statistics problems is not ideal, however, as the students are limited to the written word, use of symbols and diagrams is not possible, and facial expressions and body language are absent.

The majority of students doing the course studied did not use the online forum, and those who did mainly used it to introduce themselves to other students and to ask an occasional question. This was in keeping with the findings of Kanuka

and Anderson (1998), who found 'The greatest value of the online forum was the ability to share and receive information, as well as to *network* — not to construct new knowledge' (p. 71).

Within the discussion on the learning environment in distance education, the role of the teacher should not be overlooked. Garrison (1993) noted, 'Although the learner is ultimately responsible for learning, educationally the quality of that learning experience is established through the proactive interaction and guidance of a teacher' (p. 204). For statistics teachers this includes one-to-one tuition with students to

- clarify key points
- help the student overcome misapprehensions
- provide motivation and encouragement
- assist development of learning strategies
- provide support for the student in their studies.

Evidence that the teachers in this course were able to fulfil this role were apparent:

> *Tutor assistance was vital. Due to my serious lack of mathematical knowledge, I was constantly in need of help, even to understand what part of an equation needed to be dealt with first.*
>
> *My tutor always provided helpful advice and comments and was really positive.*

This course provided student support in the forms of a free phone line, email, and a one-day tutorial. The type of academic support most often wanted by the students studied was more face-to-face contact. It seemed that, although choosing to do this course by distance, they felt the need to have someone explain the concepts to them as well. The advantages of having tutorials include, for tutors, being able to address specific issues requested by students and being able to demonstrate concepts using diagrams and symbols and, for students, being able to form a personal relationship with their tutor. The disadvantages include the cost for both students and The Open Polytechnic and the difficulty in pitching the tutorial at a level suitable for both proficient and struggling students.

It appears, then, that while active learning of statistics can take place in a distance learning environment, the social aspects of learning are still limited by the technologies available. Motivation and metacognitive skills have been shown to support students' construction of knowledge, and these two characteristics were apparent among many of the students in this study.

## Women in statistics distance education

Vere-Jones (1995) commented:

> A very special feature of statistics... is that it breaks away from the vision of mathematics as a male-oriented subject... Traditional mathematics teaching formed part of an education programme which acted to perpetuate a tradition of male dominance. Statistics does not carry the same historical loading. (p. 14)

It is not surprising then that there appear to be few gender-specific statistics issues raised in the literature on learning statistics. There are, however, some ideas relating to learning at a distance and the way people come to know that are worth exploring in relation to learning statistics.

The research literature claims that women often prefer a collaborative approach to learning, (Kirkup & von Prummer, 1990). So the idea that women react differently from men to various forms of support is important when considering support options for a distance education statistics course. How effectively electronic forms of communication meet this need and how distance educators can facilitate such an approach has yet to be explored in the statistics learning environment.

As discussed previously, the one issue that appeared to differentiate gender was that of confidence, with women students expressing less confidence in their ability than men students. Hipp (1997) also noted the lack of confidence in women distance students and proposed: 'Teaching staff in individual subjects need to be encouraged to give positive and constructive feedback on students' work to ensure confidence is enhanced rather than further eroded' (p. 47).

The literature review discussed the work of Belenky et al. (1986) and the way women learn. Gunn (1999) noted the lack of work in this area of statistics education research and also claimed the 'emphasis on constructivism (in its various forms) means that scant attention is given to the place of informal knowledge or the role of intuition, imagination and inspiration in the construction of knowledge' (p. 248).

While the primary purpose of this research was not to investigate the ways students came to know about statistics, it was of interest to examine the statements of this group of students in relation to Belenky et al.'s (1986) 'ways of knowing'. The following table exhibits some examples found in the interview transcripts or questionnaire responses. The examples are attributed to either female (F) or male (M) respondents. The examples were chosen without knowing the gender of the respondent. This was determined subsequently from the original questionnaires and transcripts. A brief discussion of each of these categories follows.

| ***Ways of knowing*** | ***Examples*** |
|---|---|
| **Silent knowing**<br>The knower does not believe that she can learn from her own experience, and merely accepts or relies on an authority for all knowledge which she does not question. (Becker, 1995, p. 166) | When I was at school we didn't ask questions. (F) |
| **Received knowing**<br>The knower listens to the voice of authority. There is only one right answer which the teacher will dispense. (Ocean, 1998) | Statistics can be difficult if you have a bad memory. (F)<br><br>When assessments were returned, there was no answer sheet to see what the correct answers were. (F)<br>The maths made it difficult and knowing which formula to use. (F) |
| **Subjective knowing**<br>Each person's experiences yield her or his own view of reality. Truth is private; abstraction, logic and analysis are to be distrusted. (Erchick, 1996, p. 114). | Statistics is not an easy subject to learn even after you master formulas. I now know that in maths 4 + 4 can equal 9. (M)<br>I came unstuck with probability, you know, the basis of it all. I'm arrogant enough to question that the theories are right. (F) |
| **Procedural knowing (separate)**<br>Knowing is based on the use of impersonal procedures to establish truths. The goal is to be absolutely certain of what is true. (Becker, 1995, p. 166) | I took the view that if I could understand the theory and apply the right formula I would get through the process. (M)<br>There are many methods but one needs to choose the right one to achieve the result one wishes. (M) |
| **Procedural knowing (connected)**<br>Personal experiences are built on. Context is important. Connected knowing is complex, related, considers many things simultaneously. (Ocean, 1998, p. 431) | There are many facets to statistics and all play an important role in making a conclusion. (F) |
| **Constructed knowing**<br>Both separate and connected knowing are used. Answers are dependent on the context in which questions are asked and on the frame of reference of the asker. (Becker, 1995, p. 167) | I guess I see it like a good crossword — the components eventually linked, although some took a bit of working out along the way. (F) |

### *Silent knowing*

Although Belenky et al. (1986) found that there were few women in their survey demonstrating the silent way of knowing, Erchick (1996) noted that among women interviewed about their experiences of mathematics, this way was common. She commented that the traditional mathematics classroom often rewards students for their silence, as silent students place few demands on teachers. For these types of knower, 'Survival depends on blind obedience; trying to know "why" is neither important nor possible' (Erchick, 1996, p. 111). Belenky et al. (1986) found that silent knowers often came from violent, abusive backgrounds or social isolation, while Fiore (1999) noted that for some students 'math anxiety resulted from past verbal or physical abuse, in particular, abuse by a teacher or a parent while doing mathematics' (p. 1). The idea that past experiences in the home or classroom could have a dramatic impact on the way a student learns mathematics or related subjects is important and may help explain why some students, despite a lot of support, 'just don't get it'.

Within distance education, it is difficult to assess whether students are 'silent knowers' or just getting on with the job independently. Without contact with the students, the distance educator has difficulty in gauging their ability, understanding and support needs. Some students never contact their tutor and never communicate on-line. Some, but not all of these students, may be able to be classed as 'silent knowers'. These are likely to be the people who return poor assessments and who remain 'silent' despite pleas from the tutors for them to ring and get help. To be able to provide a suitable support system, there is a need for a method of identification of students for whom silent knowing is the only way of attempting to learn statistics. As Erchick (1996) noted that for many capable students 'it was only in mathematics that they found themselves maintaining positions of silence' (p112), this task becomes even more challenging for distance educators.

### *Received knowing*

The received knower, who learns by listening to the voice of authority, is familiar in most classrooms and to most distance educators. The students who commented that the statistics course was unexpectedly difficult may have underestimated the amount of cognitive engagement necessary to learn a complex and often abstract subject.

### *Subjective knowing*

The subjective knowers are beginning to be aware of their own resources and that each person's experiences work to construct their view of reality (Erchick, 1996). The idea of intuitive knowing falls within this category. Within statistics, the move towards teaching less probability theory is based on the assumption that students' intuitive ideas about probability are adequate for inferential statistics. This may be a fallacy as Garfield and Ahlgren (1988) argued that there are many misconceptions about these ideas. They also noted that it is difficult to change these misconceptions:

> Students' intuitive ideas, presumably formed through their experience, may be reasonable in many of the contexts in which students use them but can be distressingly inconsistent with the statistics concepts that we would like to teach them. (p. 50)

The subjective knower is thought to be at a crucial stage of development as they move from believing that authorities are the only ones who know to believing in their own resources, but they can create problems in a world where logic and rationality are valued attributes.

### *Procedural knowing*

Procedural knowers have moved to a stage where they do not uncritically accept the voice of authority but also do not instantly accept their intuitive voice: they begin critical thought (Erchick, 1996). There has been some debate concerning the difference between separated and connected knowing in relation to the learning of mathematics. Separate knowing is characterised by such aspects as rigour, logic, certainty and structure (Becker, 1995). In contrast, the connected knower uses shared experiences and 'explores what actions and thoughts lead to the perception that something is known' (Becker, 1995, p. 166). While not gender specific, it is thought that the two types of procedural knowing may be gender-related, with more men separate knowers and more women connected knowers. The 'connected way of being for women comes, it is argued, out of a life in which one's relationships with others and the well-being of others are a crucial part of personal development' (Kirkup, 1996, p. 151).

Becker (1995) noted that among her survey of graduate mathematics students, many mentioned being attracted to mathematics because they liked the logic and problem solving aspects and because they could tell if the problem was solved. Becker asked, 'Are women in mathematics more likely than non-mathematicians to be separate knowers and thus be attracted to the subject because, at least at this early stage, they perceive mathematics to be an objective discipline in which they can find absolute truth?' (p. 171).

There was evidence of this style of thinking from one of the women interviewees:

> *I liked having the practical things that you nutted through (rather than write 200 words) and came to the conclusion at the end.*

Nevertheless, students must come to realise that in statistics, particularly inferential statistics, all answers are tentative and dependent on certain assumptions, and have meaning only in the context from which they derive. Clayson (1998) commented, '(Students) must accept ambiguity and uncertainty as givens and abandon the notion that there is such a thing as right or wrong answers independent of context' (p. 1075). As Becker (1995) argues that for separate knowers, 'It is better to eliminate a possible truth than to accept as true something which later may prove to be false' (p. 166), it may be that separate knowers would find statistical concepts hard to grasp. Since the basis of inferential statistics is to assume a null hypothesis is true and look for evidence to reject it, the uncertainty of statistics may be unacceptable for separate knowers. They may be among the group of students who find it frustrating never to be able to prove a hypothesis true.

### *Constructed knowing*

Constructed knowers integrate the voices of expert and inner feelings with experience. The best example of constructed knowledge came from a forum entry (cited here with permission of the author):

> *I have come to the conclusion that statistics is like the 3-D pictures my daughter brought home from the library: when you first dive into it there is just so many new complex concepts facing you and it all seems such a massive complex body of knowledge. However, when you pull back slowly and look at the big picture, changing your focus, suddenly it all becomes so clear it's amazing. Just like when you finally see the hidden image in those 3-D pictures. And even then, it's so easy to lose the image again if you don't concentrate and practice putting together all the new skills and concepts.*

This student is trying to see the big picture, to connect the body of statistics knowledge to her previous knowledge and to adjust her focus. Yet she knows that to do this she needs new skills and that she will have to practise them, demonstrating a combination of connected and separate knowing, within a given context.

## Summary

Within statistical educational research, there appears to have been little work done on ways of knowing, as described by Belenky et al. (1986). Given the findings from this area of exploration in the learning of mathematics, it appears to offer an opportunity for research which could add valuable information to the literature on learning statistics.

# Bibliography


Anthony, G. (2000). Factors influencing first-year students' success in mathematics. *International Journal of Mathematics Education in Science and Technology*, *31*(1), 3–14.

Beaudoin, M. (1990). The instructor's changing role in distance education. *The American Journal of Distance Education, 4*(2), 21–29.

Becker, J. R. (1995). Women's ways of knowing in mathematics. In P. Rogers & G. Kaiser (Eds.), *Equity in mathematics education: Influences of feminism and culture* (pp. 163–174). London: Falmer Press.

Belenky, M. F., Clinchy, B. M., Goldberger, N. R., & Tarule, J. M. (1986). *Women's ways of knowing: The development of self, voice and mind*. New York: Basic Books.

Bell, J. (1998). International students have statistics anxiety too! *Education*, *118*(2), 634–636.

Billard, L. (1998). The role of statistics and the statistician. *The American Statistician*, *52*(4), 319–324.

Bradstreet, T. E. (1996). Teaching introductory statistics courses so that nonstatisticians experience statistical reasoning. *The American Statistician*, *50*(1), 69–78.

Bratton, G. (1999). The role of technology in introductory statistics classes. *The Mathematics Teacher*, *92*(8), 666–669.

Burge, E. (1988a). Beyond andragogy: Some explorations for distance learning design. *Journal of Distance Education*, *III*(1), 5–23.

Burge, E. (1988b). Foreword. In K. Faith (Ed.), *Towards new horizons for women in distance education: International perspectives.* London: Routledge.

Burge, E., & Haughey, M. (1993). Transformative learning in reflective practice. In T. Evans & D. Nation (Eds.), *Reforming open and distance education: Critical reflections from practice* (pp. 88–103). London: Kogan Page.

Burge, E., & Lenskyj, H. (1990). Women studying in distance education: Issues and principles. *Journal of Distance Education*, *V*(1), 20–37.

Burton, L. (1987). From failure to success: Changing the experience of adult learners of mathematics. *Educational Studies in Mathematics*, *18*, 305–316.

Carr-Chellman, A., Dyer, D., & Breman, J. (2000). Burrowing through the network wires: Does distance detract from collaborative authentic learning? *Journal of Distance Education*, *15*(1), 39–62.

Chance, B. (1997). Experiences with authentic assessment techniques in an introductory statistics course. *Journal of Statistics Education*, *5*(3). Retrieved February 1, 2001 from http://www.amstat.org/publications/jse/v5n3/chance.html

Chen, L. (1997, July–August). Distance delivery systems in terms of pedagogical considerations: A reevaluation. *Educational Technology*, 34–37.

Clayson, J. (1998). Confessions of a constructionist: Fifteen years of undergraduate interactions. For better or for worse. In L. Pereira-Mendoza, S. K. Lua, W. K. Tang, & W. K. Wong (Eds.), *Statistics: Expanding the network: Proceedings of the Fifth International Conference on Teaching Statistics* (Vol. 3, pp. 1075–1082). Singapore: International Association for Statistical Education.

Coulter, R. (1989). Women in distance education: Towards a feminist perspective. In R. Sweet (Ed.), *Post-secondary distance education in Canada: Policies, practices and priorities* (pp. 11–22). Athabasca University: Canadian Society for Studies in Education.

Crawford, K., Gordon, S., Nicholas, J., & Prosser, M. (1998). Qualitatively different experiences of learning mathematics at university. *Learning and Instruction*, *8*(5), 455–468.

Crawford, K., Gordon, S., Nicholas, J., & Prosser, M. (1994). Conceptions of mathematics and how it is learned: The perspectives of students entering university. *Learning and Instruction*, *4*, 331–345.

Daugherty, M., & Funke, B. (1998). University faculty and student perceptions of web-based instruction. *Journal of Distance Education*, *13*(1), 21–39.

De Corte, E. (1995). Fostering cognitive growth: A perspective from research on mathematics learning and instruction. *Educational Psychologist*, *30*(1), 37–46.

Diekhoff, G. (1996). *Basic statistics for the social and behavioural sciences*. Upper Saddle River, NJ: Prentice Hall.

Dunning, D. B., & Lai, C. (1998). Supporting the distance learning of the introductory business statistics course by telephone and e-mail. In L. Pereira-Mendoza et al. (Eds.), *Statistics: Expanding the network: Proceedings of the Fifth International Conference on Teaching Statistics* (Vol. 1, pp. 391–397). Singapore: International Association for Statistical Education.

Entwistle, A., & Entwistle, N. (1992). Experiences of understanding in revising for degree examinations. *Learning and Instruction*, *2*(1), 1–22.

Erchick, D. (1996). Women's voices and the experience of mathematics. *Focus on Learning Problems in Mathematics*, *18*(1, 2, 3), 105–122.

Evans, T. (1994). *Understanding learners in open and distance education*. London: Kogan Page.

Falk, R., & Konold, C. (1992). The psychology of learning probability. In F. Sheldon & G. Sheldon (Eds.), *Statistics for the twenty-first century* (pp. 151–164). USA: Mathematical Association of America.

Ferris, M., & Hardaway, D. (1994). Teacher 2000: A new tool for multimedia teaching of introductory business statistics. *Journal of Statistics Education*, *2*(1). Retrieved February 1, 2001, from http://www.amstat.org/publications/jse/v2n1/ferris.html

Fiore, G. (1999). Maths-abused students: Are we prepared to teach them? *The Mathematics Teacher*, *92*(5), 403–405.

Flavell, J. (1976). Metacognitive aspects of problem solving. In L. Resnick (Ed.), *The nature of intelligence* (pp. 231–236). Hillsdale, NJ: Lawrence Erlbaum.

Fong, G., Krantz, D., & Nisbett, R. (1986). The effects of statistical training on thinking about everyday problems. *Cognitive Psychology*, *18*, 253–292.

Gal, I., & Ginsburg, L. (1994). The role of beliefs and attitudes in learning statistics: Towards an assessment framework. *Journal of Statistics Education*, *2*(2). Retrieved February 1 2001 from http://www.amstat.org/publications/jse/v2n2/gal.html

Gal, I., Ginsburg, L., & Schau, C. (1997). Monitoring attitudes and beliefs in statistics education. In I. Gal & J. Garfield (Eds.), *The assessment challenge in statistics education* (pp. 37–54). Amsterdam: IOS Press.

Ganesh, S., & Ganesalingham, S. (1998). Teaching basic statistical concepts using computer display tools. In L. Pereira-Mendoza, S. K. Lua, W. K. Tang, & W. K. Wong (Eds.), *Statistics: Expanding the network: Proceedings of the Fifth International Conference on Teaching Statistics,* (Vol. 2, pp. 1001–1007). Singapore: International Association for Statistical Education.

Gardner, P., & Hudson, I. (1998). *University students' ability to apply statistical procedures: A report on the learning to apply statistics project.* Melbourne: Monash University.

Garfield, J. (1994). Beyond testing and grading: Using assessment to improve student learning. *Journal of Statistics Education*, *2*(2). Retrieved February 1 2001 from http://www.amstat.org/publications/jse/v2n1/garfield.html

Garfield, J. (1995). How students learn statistics. *International Statistical Review, 63*(1), 25–34.

Garfield, J. (1997). Discussion on new pedagogy and new content: The case of statistics. *International Statistical Review*, *65*(2), 137–141.

Garfield, J., & Ahlgren, A. (1988). Difficulties in learning basic concepts in probability and statistics: Implications for research. *Journal for Research in Mathematics Education*, *19*(1), 44–63.

Garrison, D. R. (1993). A cognitive constructivist view of distance education: An analysis of teaching-learning assumptions. *Distance Education*, *14*(2), 199–211.

Garrison, D. R., Anderson, R., & Archer, W. (2001). Critical thinking, cognitive presence, and computer conferencing in distance education. *The American Journal of Distance Education*, *15*(1), 7–23.

Garrison, D. R., & Shale, D. (1990). A new framework and perspective. In R. Garrison & D. Shale (Eds.), *Education at a distance: From issues to practice* (pp. 123–134). Florida: Krieger.

Goos, M., & Galbraith, P. (1996). Do it this way! Metacognitive strategies in collaborative mathematical problem solving. *Educational Studies in Mathematics*, *30*, 229–260.

Gordon, S. (1993). Mature students learning statistics: The activity theory perspective. *Mathematics Education Research Journal*, *5*(1), 34–49.

Gordon, S. (1995). What counts for students studying statistics? *Higher Education Research & Development*, *14*(2), 167–184.

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

Grace, M. (1991). Gender issues in distance education: A feminist perspective. In T. Evans & B. King (Eds.), *Beyond the text: Contemporary writing on distance education* (pp. 56–76). Geelong, VIC: Deakin University Press.

Grote, B. (2000). *Student retention and support in open and distance learning*. Lower Hutt, NZ: The Open Polytechnic of New Zealand.

Gunn, S. (1999). Emerging themes in statistics education. In J. Truran & K. Truran (Eds.), *Making the difference: Proceedings of the 22nd annual conference of the Mathematics Education Research Group of Australasia* (pp. 246–252). Sydney, NSW: MERGA.

Hawkins, A., Joliffe, F., & Glickman, L. (1992). *Teaching statistical concepts*. London: Longman.

Henri, F., & Haughey, M. (2000). Editorial. *Journal of Distance Education*, *15*(1), i–ii.

Hill, J. (1997). Distance learning environments via the World Wide Web. In B. Kahn (Ed.), *Web-based instruction* (pp. 75–80). Englewood Cliffs, NJ: Educational Technology Publications.

Hipp, H. (1997, June). Women studying at a distance: What do they need to succeed? *Open Learning*, 41–49.

Ho H., Senturk, D., Lam, A., Zimmer, J., Hong, S., & Okamoto Y. (2000). The affective and cognitive dimensions of math anxiety: A cross-national study. *Journal for Research in Mathematics Education*, *31*(3), 362–379.

Hogg, R. (1991). Statistical education: Improvements are badly needed. *The American Statistician*, *45*(4), 342–343.

Hubbard, R. (1997). Assessment and the process of learning statistics. *Journal of Statistics Education*, *5*(1). Retrieved February 1 2001 from http://www.amstat.org/publications/jse/v5n1/hubbard.html

Jegede, O. J., & Kirkwood, J. (1994). Students' anxiety in learning through distance education. *Distance Education*, *15*(2), 279–290.

Jonassen, D., Davidson, M., Collins, M., Campbell, J., & Bannan Haag, B. (1995). Constructivism and computer-mediated communication in distance education. *The American Journal of Distance Education*, *9*(2), 7–26.

Kanuka H., & Anderson, T. (1998). Online social interchange, discord, and knowledge construction. *Journal of Distance Education*, *13*(1), 57–74.

Kember, D. (1994). The teacher is more important than the medium: Pre-packaged instructional materials are not axiomatic with surface learning. *Distance Education*, *15*(1), 153–159.

Kirkup, G. (1996). The importance of gender. In R. Mills & A. Tait (Eds.), *Supporting the learner in open and distance learning,* (pp. 146–164). London: Pitman.

Kirkup, G., & von Prummer, C. (1990). Support and connectedness: The needs of women distance education students. *Journal of Distance Education*, *V*(2), 9–31.

Konold, C. (1995). Issues in assessing conceptual understanding in probability and statistics. *Journal of Statistics Education*, *3*(1). Retrieved February 1 2001 from http://www.amstat.org/publications/jse/v3n1/konold.html

Leder, G., & Forgasz, H. (1998). Tertiary mathematics: Perceptions of school leavers and mature-age students. In C. Kanes, M. Goos, & E. Warren (Eds.), *Teaching mathematics in new times: Proceedings of the 21st Annual Conference of the Mathematics Education Research Group of Australasia* (pp. 311–318). Brisbane, QLD: MERGA.

Lunn, D. (1998). An overview of statistical education at a distance. In L. Pereira-Mendoza et al. (Eds.), *Statistics: Expanding the network: Proceedings of the Fifth International Conference on Teaching Statistics* (Vol. 1, pp. 399–400). Singapore: International Association for Statistical Education.

Ma, X. (1999). A meta-analysis of the relationship between anxiety toward mathematics and achievement in mathematics. *Journal for Research in Mathematics Education*, *30*(5), 520–540.

Maher, E. (1998). Does the delivery media impact student learning? A case study. *Open Learning*, *13*(3), 27–32.

Martens, R., Valcke, M., Portier, S., Weges, H., & Poelmans, P. (1997). Research with interactive learning environments in three content domains: Descriptive statistics, continuous mathematics and substantive criminal law. *Distance Education*, *18*(1), 44–58.

May, S. (1993). Collaborative learning: More is not necessarily better. *The American Journal of Distance Education*, *7*(3), 39–49.

May, S. (1994). Women's experiences as distance learners: Access and technology. *Journal of Distance Education*, *IX*(1), 81–98.

McAlevey, L., & Stent, A. (1999). Undergraduate perceptions of teaching of a first course in business statistics. *International Journal of Mathematics Education in Science and Technology*, *30*(2), 215–225.

McAlpine, I. (2000). Collaborative learning online. *Distance education*, *21*(1), 66–80.

McLeod, D. (1992). Research on affect in mathematics education: A reconceptualization. In D. Grouws (Ed.), *Handbook of research on mathematics teaching and learning* (pp. 575–596). New York: MacMillan.

Moore, D. (1997). New pedagogy and new content: The case of statistics. *International Statistical Review*, *65*(2), 123–165.

Morrow, C. (1996). Women and mathematics: Avenues of connection. *Focus on learning problems in mathematics*, *18*(1,2,3), 4–16.

Mosteller, F. (1988). Broadening the scope of statistics and statistical education. *The American Statistician*, *42*, 93–99.

Ocean, J. (1998). Identifying separate and connected knowing in mathematics education. In C. Kanes, M. Goos, & E. Warren (Eds.), *Teaching mathematics in new times: Proceedings of the 21st annual conference of the Mathematics Education Research Group of Australasia* (Vol. 2, pp. 428–435). Brisbane, QLD: MERGA.

Onwuegbuzie, A. (1999). Statistics anxiety among African American graduate students: An affective filter? *Journal of Black Psychology*, *25*(2), 189–209.

O'Rouke, J. (1999). Canaries in the mine: Women's experiences and new learning technologies. In A. Tait & R. Mills (Eds.), *The convergence of distance and conventional education: Patterns of flexibility for the individual learner* (pp. 100–109). London: Routledge.

Parker, R., Pettijohn, C., & Keillor, B. (1999). The nature and role of statistics in the business school curriculum. *Journal of Education for Business*, *75*(1), 51–54.

Patrick, R. (1999). Not your usual maths course: Critical mathematics education for adults. *Higher Education Research & Development*, *18*(1), 85–98.

Paul, R. (1990). *Open learning and open management: Leadership and integrity in distance education*. London: Kogan Page.

Pfannkuch, M. (1996). *Statistical interpretation of media reports*. Paper presented at the New Zealand Statistical Association 47th Annual Conference, Wellington.

Pfannkuch, M., & Brown, C. (1996). Building on and challenging students' intuitions about probability: Can we improve undergraduate learning? *Journal of Statistics Education*, *4*(1). Retrieved February 1 2001 from http://www.amstat.org/publications/jse/v4n1/pfannkuch.html

Phillips, B., Francis, G., & Hutcheson, M. (1998). Statistics for workers in social and health sciences by flexible learning modes. In L. Pereira-Mendoza et al. (Eds.), *Statistics: Expanding the network: Proceedings of the Fifth International Conference on Teaching Statistics* (Vol. 1, pp. 401–407). Singapore: International Association for Statistical Education.

Reeves, T., & Reeves, P. (1997). Effective dimensions of interactive learning on the World Wide Web. In B. Kahn (Ed.), *Web-based instruction* (pp. 59–66). Englewood Cliffs, NJ: Educational Technology Publications.

Roberts, D., & Bilderback, E. (1980). Reliability and validity of a statistical attitude survey. *Educational and Psychological Measurement*, *40*, 235–238.

Roiter, K., & Petocz, P. (1996). Introductory statistics courses: A new way of thinking. *Journal of Statistics Education*, *4*(2). Retrieved February 1 2001 from http://www.amstat.org/publications/jse/v4n2/roiter.html

Rossman, A. J. (1996). *Workshop statistics*. New York: Springer-Verlag.

Rossman, A., & Chance, B. (1999). Teaching the reasoning of statistical inference: A "top ten" list. *The College Mathematics Journal*, 30(2), 297–305.

Scheaffer, R., Gnanadesikan, M., Watkins, A., & Witmer, J. (1996). *Activity-based statistics*. New York: Springer-Verlag.

Schuyten, G., & Dekeyser, H. (1998). An electronic learning environment for applied statistics: Quality care and statistics education in higher education. In L. Pereira-Mendoza, S. K. Lua, W. K. Tang, & W. K. Wong (Eds.), *Statistics: Expanding the network: Proceedings of the Fifth International Conference on Teaching Statistics* (Vol. 2, pp. 711–716). Singapore: International Association for Statistical Education.

Seaton, W. (1993). Computer-mediated communication and student self-directed learning. *Open Learning*, *8*(2), 49–54.

Sharma, S. (1996). The relationship between statistics and probability. *SAMEpapers 1996* (pp. 93–110). Hamilton, NZ: Centre for Science and Mathematics Education Research, University of Waikato.

Simonson, M., Smaldino, S., Albright, M., & Zvacek, S. (2000). *Teaching and learning at a distance: Foundations of distance education*. Upper Saddle River, NJ: Prentice Hall.

Snee, R. (1993). What's missing in statistical education? *The American Statistician*, *47*(2), 149–154.

Stacey, E. (1999). Collaborative learning in an on-line environment. *Journal of Distance Education*, *14*(2), 14–33.

Sutherland, P. (1997). The implications of research on approaches to learning for the teaching of adults. In P. Sutherland (Ed.), *Adult learning: A reader* (pp. 192–200). London: Kogan-Page.

Tanur, J. M. (1997). Discussion: Leading horses to water. *International Statistical Review*, *65*(2), 159–161.

Taylor, P. (1996). Reflections on students' conceptions of learning and perceptions of learning environments. *Higher Education Research and Development*, *15*(2), 223–237.

Tobias, S. (1993). *Overcoming math anxiety* (2nd ed.). New York: W.W. Norton.

Townsend, M., Moore, D., Tuck, B., & Wilton, K. (1998). Self-concept and anxiety in university students studying social science statistics within a co-operative learning structure. *Educational Psychology*, *18*(1), 41–54.

Vere-Jones, D. (1995). The coming of age of statistical education. *International Statistical Review*, *63*(1), 3–23.

Watson, J. (2000). Statistics in context. *The Mathematics Teacher*, *93*(1), 54–58.

Watts, D. G. (1991). Why is introductory statistics difficult to learn? And what can we do to make it easier? *The American Statistician*, *45*, 290–291.

White, C. (1997). Effects of mode of study on foreign language teaching. *Distance Education*, *18*(1), 178–196.

White, C. (1999). The metacognitive knowledge of distance learners. *Open Learning*, *14*(3), 37–46.

Wild, C. J. (1994). On embracing the 'wider view' of statistics. *The American Statistician*, *48*(2), 163–171.

Wild, C., Triggs, C., & Pfannkuch, M. (1997). Assessment on a budget: Using traditional methods imaginatively. In I. Gal & J. Garfield (Eds.), *The assessment challenge in statistics education* (pp. 205–220). Amsterdam: IOS Press.

Williams, A. (1999). Novice students' conceptual knowledge of statistical hypothesis testing. In J. Truran. & K. Truran. (Eds.), *Making the difference: Proceedings of the 22nd Annual Conference of the Mathematics Education Research Group of Australasia*, pp. 554–560). Sydney, NSW: MERGA.

Wilson, J. (1998). Metacognition within mathematics: A new and practical multi-method approach. In C. Kanes, M. Goos, & E. Warren (Eds.), *Teaching mathematics in new times: Proceedings of the 21st Annual Conference of the Mathematics Education Research Group of Australasia* (Vol. 2, pp. 693–700). Brisbane, QLD: MERGA.

Wise, S. (1985). The development and validation of a scale measuring attitudes toward statistics. *Educational and Psychological Measurement*, *45*, 401–405.

Young, G., & Marks-Maran, D. (1998). Using constructivism to develop a quality framework for learner support: A case study. *Open Learning*, *13*(2), 30–37.