24. LEARNING THE UNLIKELY AT DISTANCE AS AN INFORMATION TECHNOLOGY ENTERPRISE: DEVELOPMENT AND RESEARCH

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Research and development (R&D) is an integral part of successful industrial and "big business" practice and expansion. Although there is a similar nexus espoused in education, there is, at best, a tenuous link between most educational practice and theoretical constructs. Even where those links exist, the construct itself may be the only aspect to be subject to thorough academic scrutiny; the "practice" resulting from the construct is not always examined in ways that lead to the construct being progressively enhanced. The rapid rise and expansion of technology, particularly computer technology accessible in the classroom, imply a change-of-practice imperative. Development itself needs to be followed by research to test the efficacy of innovation within practice. Nowhere is this more pressing than in the field of statistics education, where technological innovations abound, indeed are implicit, in continuing development. A good feeling about an innovation is not enough to indicate its validity in terms of producing change.

The purpose of this paper is to explore the reverse juxtaposition--development and research (D&R)--of the expanding use of technology in teaching and learning statistics. The context for the discussion is an Australian experience associated with a professional development project for teachers in the area of Chance and Data. The reversal of order is significant in this context due to the necessity for development of technologies before their impact can be assessed. The technological innovations relate, first, to the delivery of professional development content to teachers separated by distance and, second, to the multimedia preparation of content. The purpose of this discussion is to address the evaluation of innovation in an acceptable research framework. First, the development of a multimedia program for teacher professional development will be described. Then a research model for evaluating its effectiveness will be advanced.

DEVELOPMENT

The need for the development of a package for the professional development of teachers of probability and statistics is based on reports from several sources. Callingham, Watson, Collis, and Moritz (1995), for example, found differences in perceptions of the use of statistics and in personal confidence in teaching statistics among male and female and primary and secondary teachers. Greer and Ritson (1993) found teachers at all levels in need of in-service training in data handling. Because statistics is a new area of the mathematics curriculum, it is acknowledged that there is a need for content knowledge, as well as teaching method and experience with new technologies to assist student learning, particularly at the middle school level.

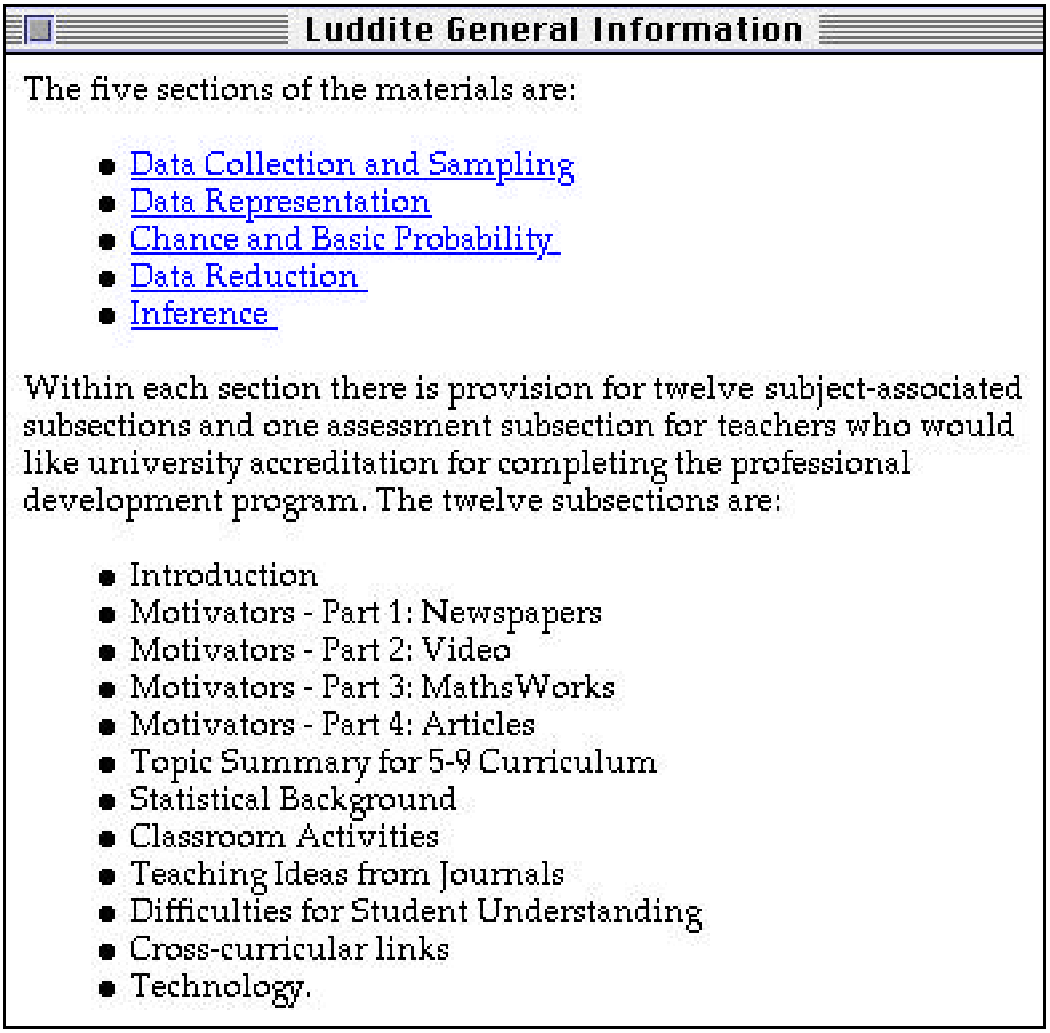
From July, 1994 to April, 1995, the Department of Employment, Education and Training (DEET) in Australia funded a professional development project run by the Australian Association of Mathematics Teachers, Inc. (AAMT) to explore the provision of statistics education for teachers separated by great distances in Australia. The project was titled "Learning the Unlikely at Distance as an Information Technology Enterprise" and shortened to LUDITE. Although the term "unlikely" may appear to reflect probabilistic content, the project was aimed at both the Chance and Data components of the Australian mathematics curriculum (Australian Education Council, 1991, 1994). This aspect of the program followed an earlier AAMT DEET-funded project that provided materials for professional development workshops to disseminate the content of *A National Statement on Mathematics for Australian Schools* (Australian Education Council, 1991). The *MathsWorks: Teaching and Learning Chance and Data* workshop (Watson, 1994b) produced for this earlier project was the basis for initial planning in the LUDITE project. It consisted of 10 modules to be used in face-to-face workshop settings with teacher and/or parent groups. Although not intended as a course to cover all aspects of Chance and Data, the modules provided activities to motivate further interest and learning.

The LUDITE project produced four satellite television narrowcasts to schools in two states to test available television technology. The programs were interactive to the extent that schools could reply by fax or telephone to requests made by presenters during the program. Several other aspects of information technology were explored during the series, including the telecast of prepackaged videos. Australian-produced television news stories were purchased and two videotapes were professionally produced for the project--one showed a grade 5 class conducting a simulation activity and one demonstrated how to set up a school-based computer network. A Ford motor company television advertisement and excerpts from *Statistics: Decisions through Data* (Moore, 1992) were also shown. Although it was not possible to show Microsoft Powerpoint slides from the studio computer over the narrowcast network, a laptop computer was connected to demonstrate the linkage to a network and the ability to use bulletin boards and simulation software. For two narrowcast sessions, four teachers came to the studio to carry out the activities prepared for teachers; this assisted the presenters in judging the amount of time to be off air for local interactive work. In the last session, a panel discussed curriculum issues and encouraged similar discussion in the schools. Evaluation of the project was made not only by the presenters in the studio (Watson, Baxter, Olssen, & Lovitt, 1996) but also by a three-member team at various receiving sites (Palmer, Probert, & Brinkworth, 1995).

Although the reaction of teacher participants who viewed the narrowcasts live and conducted activities in their schools was positive in terms of the content, the presentation, and the limited interaction (Palmer et al., 1995), it was impossible to determine exactly how many schools viewed the telecasts. This was related to several difficulties with using the satellite system. Although over 2,000 schools possessed satellite dishes, only a small percentage of these were operational. Difficulties with booking time by an outside agency (the AAMT) meant that each of the four narrowcasts was transmitted at a different time of day. This made planning in schools difficult. The lack of ability of the presenters to see the participants was a further drawback and some schools were reticent in using the telephone and fax lines for communication.

At the conclusion of the LUDITE project, it was evident that a technology other than satellite television needed to be used for professional development and that a more complete set of support materials was required. From July, 1995 to April, 1996, a second stage of the project was funded under the expanded title "Learning the Unlikely at Distance Delivered as an Information Technology Enterprise" (LUDDITE). The two significant changes in the second year were the use of videoconferencing for dissemination and the provision of a set of multimedia materials to be used for the equivalent of a 30-hour professional development program. The videoconferences introduced and motivated the use of the multimedia package.

The multimedia package included the text, *Statistics: Concepts and Controversies* (Moore, 1991), extracts from the *Statistics: Decisions through Data* video series (Moore, 1992), software to conduct probability simulations (Konold & Miller, 1992b), and data analysis (Konold & Miller, 1992a), and a hypertext documentation readable by Netscape or a suitable browser. The hypertext front page included a table of contents and provided other relevant administrative information and links to resources. The main structure and sections are shown in Figure 1, which is a screen dump of the hypertext, read using Netscape. There were also links to Australian and United States curriculum documents (Australian Education Council, 1991, 1994; National Council of Teachers of Mathematics, 1989). The package was intended to cover all aspects of teaching Chance and Data in the middle school years.


Luddite General Information

The five sections of the materials are:

- Data Collection and Sampling
- Data Representation
- Chance and Basic Probability
- Data Reduction
- Inference

Within each section there is provision for twelve subject-associated subsections and one assessment subsection for teachers who would like university accreditation for completing the professional development program. The twelve subsections are:

- Introduction
- Motivators - Part 1: Newspapers
- Motivators - Part 2: Video
- Motivators - Part 3: MathsWorks
- Motivators - Part 4: Articles
- Topic Summary for 5-9 Curriculum
- Statistical Background
- Classroom Activities
- Teaching Ideas from Journals
- Difficulties for Student Understanding
- Cross-curricular links
- Technology.

Figure 1: Structure of the LUDDITE materials

The videoconferencing was conducted from a hub established through the Technical and Further Education (TAFE) system in Australia, based in Adelaide. Technical difficulties, however, prevented a link from being established to Tasmania (the site of the first author). Hence, it was necessary for her to travel to Adelaide for each videoconference with mainland Australian sites: Adelaide, Alice Springs, Brisbane, Mount Gambier, Perth, and Townsville (shown in Figure 2). Separate sessions were also arranged from Hobart on a University of Tasmania system to a single site within Tasmania (Burnie, 400 km from Hobart). Five sessions were held from the Adelaide hub and six between Hobart and Burnie. Except for slight changes due to Easter breaks in schools, sessions were scheduled for between one and two hours at two-week intervals beginning in February, 1996. The number of participants at the six mainland sites varied from two to six depending on the week; at Burnie 10 teachers in the region were invited to participate.

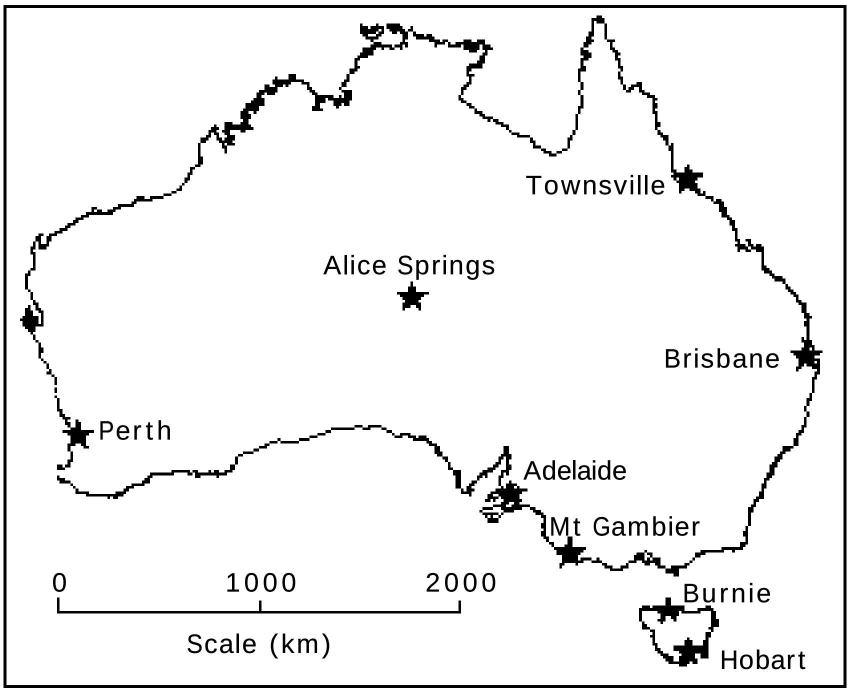


Figure 2: Sites for LUDDITE videoconferences throughout Australia

Detailed evaluation of the LUDDITE project is given elsewhere in terms of the reactions to the videoconferencing and hypertext (Watson, 1996). With reference to the multimedia materials, once frustrations with the installation of software were overcome, reactions to the hypertext were generally positive. Some participants experienced initial difficulty navigating the hypertext but introduction to the *Back* button and *Go* menu helped, as did discussion of the different mental models readers of hypertext may be using (Jih & Reeves, 1992). The text and video were thought appropriate by teachers of grades 5 to 9, the target group for the LUDDITE project. A color-coded hard copy of the hypertext documentation was provided and was considered a good backup for nonscreen reading of content. It was interesting that cognitive preferences led some first to explore the text, some the hypertext, some the video and some the software. This was determined by the availability of equipment only to a small extent.

The participants and presenters became more comfortable with the videoconferencing as the sessions progressed. One advantage of the system is that the videoconferencing links use telephone cabling, which allows access to over 3,000 sites. A weakness, however, is that video transmission is reduced to approximately seven frames per second, only about 25% of the normal television transmission rates in the

Australian Pal-D standard. This meant it was not realistic to show video material because of low frame rates. However, from Adelaide it was possible to transmit computer screen images directly; hence, software demonstrations were possible. Participants could work on their own computers in the local studios with the presenters; this was a particularly popular aspect of the videoconferences. Overall, it was felt that videoconferencing was more successful than satellite television because of this and the “face-to-face” interaction.

The next stage of the LUDDITE project will produce a CD-ROM with improved or elaborated discussions based on feedback from participants in the 1995-96 project. The CD-ROM will include expanded software documentation, revised presentation of news media materials, and computer-based video clips. At the same time, electronic mail communication with the presenters will be introduced, and certification from a university for those desiring a postgraduate qualification in statistics education will be offered. At the end of the third stage of the project, it is hoped that a product will be available that will provide a multimedia presentation of materials that is accessible anywhere in Australia (with computer facilities) and a link to the presenters that can be accessed by teachers at all times, rather than at fixed intervals in fixed locations.

There are many questions that arise at each stage of a pilot project such as this. How much evaluation can be done within the time frame of the project’s funding? What kind of evaluation is adequate to predict what will happen if a school system implements the professional development program? What equity issues are involved in terms of schools’ and/or teachers’ ability to access the equipment necessary to take part in multimedia projects? What limits exist in the technology and are these detrimental to communicating the professional development message (e.g., the limitations of videoconferencing in comparison to what is seen on television news and cross-continent talk-back programs)? Although longitudinal monitoring would seem warranted to follow changes in teacher behavior, student outcomes, and technological access by systems, it is impossible within the yearly funding structure of DEET projects.

These issues lead to the acknowledgment of a need for a research model for assessing the effectiveness of a multimedia professional development package within an operating educational system. The rest of this paper focuses on evaluating outcomes for teachers and students as a result of technology-based professional development rather than on the technological issues themselves, although these may affect the implementation of a professional development program.

RESEARCH

Although projects such as the three-stage one funded by DEET demonstrate that it is possible to create and deliver professional development in statistics education to teachers using the current information technologies, this is only the first step in achieving change in the delivery of the curriculum across a country as vast as Australia. Although teachers who participated in the pilot trials were positive in their feedback, they were volunteers who had some motivation to increase their knowledge of chance and data and/or their experience with new technologies. Their responses may not be typical of teachers across the country. What is needed is a genuine, monitored trial of the materials in a system willing to recruit nonspecialist teachers for a planned professional development program and to ask these teachers and their students to participate in the measurement of variables before and after to assist in detailed assessment of the effectiveness of the program.

The model to be proposed to evaluate the effectiveness of the professional development is different from that used previously by others to investigate methods of improving student outcomes in relation to classroom methodology and experiences. Previous experimental or quasi-experimental designs imposed a teaching method on students, often with the teaching delivered by the researchers or specially selected expert teachers (e.g., Campbell & Stanley, 1963). In such research, it was often difficult to ascertain whether factors other than those controlled for had influenced outcomes, and little information was available on what would happen if ordinary classroom teachers tried to implement such methods, particularly if the teachers lacked the knowledge, confidence and enthusiasm of the researchers or hand-chosen teachers. Figure 3 shows that classroom teachers were only involved after the research was finished. Although there is an indication that research of the type carried out under the model in Figure 3 benefits those children involved in the research project (e.g., Yackel, Cobb, & Wood, 1992), there is an absence of evidence that the methods are used outside of the research environment in classrooms on a regular basis.

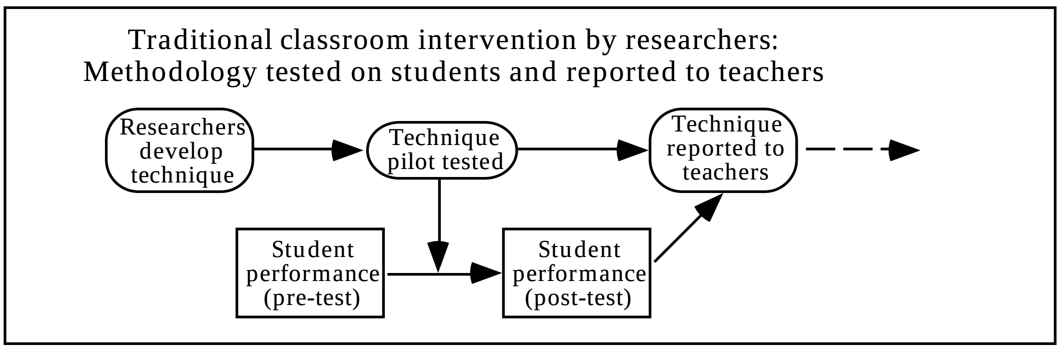


Figure 3: Traditional research model

There is a plethora of literature suggesting innovative methods of providing professional development for mathematics teachers (e.g., Aichele & Coxford, 1994; Nolder & Johnson, 1995; Redden & Pegg, 1993), and even more for teachers of probability and statistics (Green, 1992). Far fewer reports, however, mention evaluations that have found long-term measurable changes, and those that do often describe changes in teacher attitude rather than changes in content knowledge or student outcomes. Laing and Meyer (1994), for example, looked at comfort level and class time spent on topics by teachers; Watterson (1994) used samples of children's work to confirm teachers' continued use of investigational approaches. No studies could be found in the mathematics education literature that reported measuring student and teacher outcomes as suggested below. Green (1992) reports none in his review of the data handling literature and at the same time makes a plea for longitudinal research. One of the major reasons that a rigorous method of evaluation is required is that there is some evidence indicating that even the most well-intended professional development for teachers may not lead to changes in teacher practice (e.g., Thompson, 1989).

The proposed research model would involve the recruitment of classroom teachers with no special pre-existing expertise in Chance and Data. They would be involved in the program of professional development based on the LUDDITE multimedia materials. The specific teaching methodology and syllabus to be used in classrooms would be decided by the classroom teachers participating in the research, rather than imposed by the researchers. It is our belief that teachers are in the best position to make decisions to facilitate their students' learning if they have adequate preparation. Hence, the professional development provided to the teachers seeks to anticipate teachers' needs and allow teacher-input where they felt necessary to choose the direction of the training. This more complex model is shown in Figure 4. The provision of a multimedia-based professional development package (e.g., LUDDITE) is the major component of the input in the first row of the model in Figure 4. Valid ways of monitoring the potential changes that take place in the behaviors and/or beliefs of the teachers and in the outcomes achieved by their students in relation to their Chance and Data curriculum are also needed. Some suggestions for how this might be done will be outlined below, based on previous experience and research carried out in Australia in recent years.

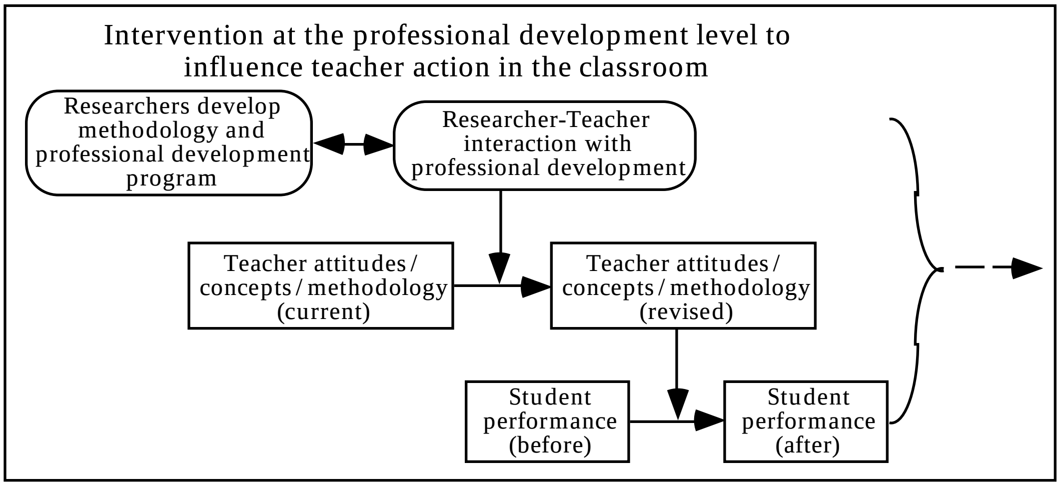


Figure 4: Monitored professional development model for obtaining classroom change

Teachers

The evaluation of teacher change referred to in the second row of Figure 4 could be based on profiles of the characteristics associated with the teaching of chance and data. These would be monitored using teacher interviews and written questionnaires and include the following: confidence in teaching particular topics, opinions on the social uses of statistics, academic experience in statistics, previous professional development in Chance and Data, exposure to documents related to the implementation of the Chance and Data curriculum, years of teaching experience, methods of teaching Chance and Data in general, methods of teaching about average, methods of teaching about sampling, and responses to selected items answered by students.

Most of these variables are self-explanatory. The opinions on social uses of statistics could be gauged from scales such as one developed by Gal and Wagner (1992). Figure 5 provides four examples from the Gal and Wagner scale. These items ask for responses of agreement or disagreement on a Likert-type scale. The types of items that could be used for responses to student answers are shown below (see Figures 6-8). Initial data available from previous Australian research indicate that there are differences in perceptions of the use of statistics in society and in teachers' confidence in teaching Chance and Data topics among male and female and primary and secondary teachers, with some groups' responses causing concern to the researchers (Callingham et al., 1995). Other research (Callingham, 1993) also indicates that teachers' understanding of the fundamental concept of arithmetic mean is lacking--many were unable to apply it outside a straightforward calculation context.

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Personal statements:
• I can easily read and understand graphs and charts in
  newspaper articles.
• I could easily explain how an opinion poll works.

Society statements:
• You need to know something about statistics to be an
  intelligent consumer.
• People who have contrasting views can each use the same
  statistical finding to support their view.
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Figure 5: Examples of items from Gal and Wagner (1992)

In the Australian context, the transcripts of teacher interviews and of the written questionnaires, available from 72 teachers from Kindergarten to Grade 10 from all seven school districts in Tasmania, are being analyzed by NUD•IST (Qualitative Solutions & Research, 1992), a language analysis software program that categorizes verbal responses. Quantitative statistics are also being used when appropriate. The qualitative and quantitative variables are being combined to develop a profile of teacher attitude, competence, and behavior in relation to the SOLO Taxonomy (Biggs & Collis, 1982, 1989, 1991; Collis & Biggs, 1991). This model, which describes levels of sophistication (from unistructural to multistructural to relational), is an appropriate model for structuring the observations of teacher outcomes in relation to most of the factors related to the teaching of Chance and Data. Pegg (1989) has previously used the SOLO model to consider the structure of classroom lessons, and it is expected that the dimensions in the profile will include attitudes (affective domain), concepts (cognitive domain), teaching methodology and previous experience. The SOLO model is being used for at least two of the dimensions (concepts and methodology).

The results of this part of the analysis of existing teacher data are being considered in relation to other sources, such as the *National Competency Framework for Beginning Teaching* (National Project on the Quality of Teaching and Learning, 1996) and the *Professional Standards for Teaching Mathematics* (National Council of Teachers of Mathematics, 1991), in order to develop a total profiling model. The NPQTL project produced a framework for considering the competence of beginning teachers. Following this, a framework for practicing teachers will be proposed. The five areas in the framework reflect many of the aspects highlighted in the previous research referred to above; that is, using and developing professional knowledge and values; communicating, interacting and working with students; planning and managing the teaching and learning process; monitoring and assessing student progress and learning outcomes; and reflecting, evaluating, and planning for continuous improvement. These factors, as well as those mentioned above, provide a foundation from which the teaching of chance and data can be examined.

Overall, there is a need to monitor teacher change in both the short term and the long term. Many factors are involved and methods such as those described here are likely to be required to develop a complete picture of the nature of change.

Students

The assessment of change in student performance shown in the third row of Figure 4 could be conducted using pretests and posttests, and, in the Australian context, the data base provided by previous research. It would be possible to assess student outcomes from the classes of the teachers involved in the project using a short answer/multiple choice questionnaire and a media survey. These instruments were developed as part of an earlier research project, in which an extensive longitudinal study of students in Tasmanian schools in relation to the Chance and Data part of the mathematics curriculum was conducted (Watson, 1992, 1994a; Watson & Collis, 1993, 1994; Watson, Collis, & Moritz, 1994, 1995). This was the first study of its kind in Australia and contributed to our knowledge of how students develop an understanding of the concepts in the field over time. The study began just as the Guidelines for Chance and Data K-8 were being released into Tasmanian state schools, which reflected national curriculum changes in mathematics (Australian Education Council, 1991; Department of Education and the Arts, 1993). Schools in all seven districts of the state system were surveyed and student outcomes data for the first two years of the curriculum implementation is available. Analyses are being conducted using NUD•IST in association with the SOLO model, as well as *t*-tests for longitudinal paired and unpaired comparisons. The norms for student understanding developed from this project would provide the benchmark in Australia for monitoring student outcomes in the evaluation of the overall model in Figure 4. It would be possible to make comparisons with other students in the same grades and to make judgments of the improvements made by students over the period of their teachers' involvement in the project.

The items to be used with students would include some used by other researchers (e.g., Fischbein & Gazit, 1984; Konold & Garfield, 1992; Pollatsek, Well, Konold, Hardiman, & Cobb, 1987) to explore basic concepts. Three exemplary items from this other research that have been used previously (Watson et al., 1994, 1995a, 1996) are shown in Figure 6. These items cover luck, intuitive conditional probability, and an understanding of average. Items that explore basic concepts are shown in Figure 7 (Moritz, Watson, & Pereira-Mendoza, 1996). Because of the application of the Chance and Data content in a social context (Australian Education Council, 1991), items from the media would monitor another important aspect of the teaching of the curriculum. The two items shown in Figure 8 illustrate the concepts that could be monitored (Moritz, Watson, & Collis, 1996; Watson et al., 1995b). The items chosen would reflect the five components of the curriculum as covered in the five sections of the LUDDITE materials noted in Figure 1.

Application of the model

Evaluating the model in Figure 4 requires a system setting in which the professional development could take place and be monitored. Such a system exists in Tasmania, provided funding could be supplied by the schools for the professional development and by another agency for a research project to conduct the monitoring process. A feasible research project would include 40 or more grade 5-9 teachers (two each from 20 or more schools). These teachers would negotiate and participate in a professional development program based on the LUDDITE materials and run by an expert teacher in the system. Depending on the education system and the distances involved, the use of satellite television or videoconferencing might assist delivery. A three-year project would appear necessary to follow through the evaluation of a multimedia professional development program.

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Every morning, James gets out on the left side of the bed.
He says that this increases his chance of getting good marks.
What do you think?

Please estimate:
     (a) The probability that a woman is a school teacher.
     (b) The probability that a school teacher is a woman.

To get the average number of children per family in a town,
a teacher counted the total number of children in the town.
She then divided by 50, the total number of families.
The average number of children per family was 2.2.
Tick which of these is certain to be true.
☐(a)Half of the families in the town have more than 2 children.
☐(b)More families in the town have 3 children than have 2 children.
☐(c)There are a total of 110 children in the town.
☐(d)There are 2.2 children in the town for every adult.
☐(e)The most common number of children in a family is 2.
☐(f)None of the above.
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Figure 6: Examples of items from other research

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If someone said you were “average”, what would it mean?

What things happen in a “random” way?

If you were given a “sample”, what would you have?
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Figure 7: Items to explore basic concepts

North at 7-2

But we can still win match, says coach

What does "7-2" mean in this headline about the North against South football match? Give as much detail as you can.

From the numbers, who would be expected to win the game?

Decriminalise drug use: poll

SOME 96 percent of callers to youth radio station Triple J have said marijuana use should be decriminalised in Australia.
The phone-in listener poll, which closed yesterday, showed 9924 - out of the 10,000-plus callers - favoured decriminalisation, the station said.
Only 389 believed possession of the drug should remain a criminal offence.
Many callers stressed they did not smoke marijuana but still believed in decriminalising its use, a Triple J statement said.

What was the size of the sample in this article?

Is the sample reported here a reliable way of finding out public support for the decriminalisation of marijuana? Why or why not?

Figure 8: Examples of media items

It is likely such a program would require five or six release days from school over the first year of the project. Although the participants might generate ideas during the professional development program, the main emphasis would be on the planning and execution of a classroom Chance and Data program during the second year. The teachers would be interviewed in relation to the profile described earlier at the beginning of the project, during the second year, and again in the third year, to evaluate long-term ability to sustain change. Students in the teachers' classes would be pretested and posttested using the content instruments such as those described above, at the beginning and end of the second year of the project and again in the third year to examine long-term retention of concepts. Affective feedback could also be sought from students. This could be done in an open-ended fashion and analyzed using NUD•IST.

The benefits of such a research program for the system involved include the following in Australia:

1. There is a good multimedia professional development program for its teachers due to the DEET-funded projects that produced and evaluated the materials.
2. There is the opportunity to monitor change and assess the effectiveness of the program in terms of teacher beliefs, behavior, and knowledge, and student outcomes--something that the literature

illustrates rarely happens in practice.

3. There may be the opportunity to apply the evaluation model to other areas of the school curriculum.

It is expected that other countries have professional development packages similar to LUDDITE that could be used as a basis for engaging in similar research to assess the effectiveness of multimedia professional development programs.

CONCLUSION

The need for "development" in the area of information technologies for the delivery of professional development to teachers of chance and data, particularly in countries where distance is a mitigating factor, is almost universally acknowledged. The need for "research" to evaluate the effectiveness of such programs has been virtually ignored. As well as describing the development of a technology-based professional development package, this paper has presented a model for assessing the effectiveness of a professional development program using profiles of teachers and outcomes of students. It is hoped that both the systems and the funding can be found to put the scheme into practice in Australia, and that similar models for research will be used in other countries that have newly devised multimedia professional development programs to meet curriculum demands. In fact, what we are proposing is an R-D-R model that effectively uses both theoretical research and professional development packages to lead to further research (see Figure 9). This incorporates both the R&D and D&R needed to improve the statistics education of our students.

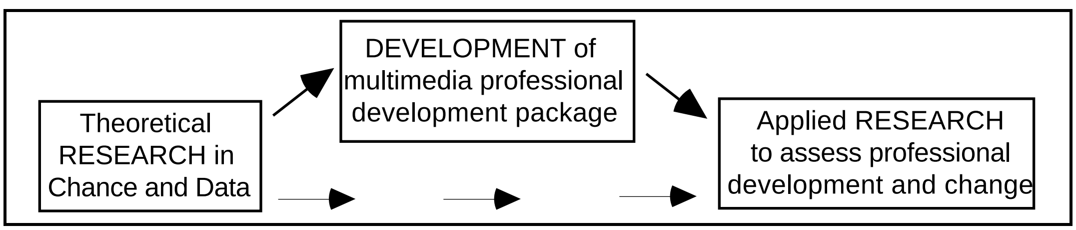

Figure 9: "R-D-R" continuing model

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