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ABSTRACT

Though statistical literacy is an essential skill in modern society, students often approach statistics courses with apprehension and "mathophobia." Educators need to design and deliver statistics instruction so as to counter these anxieties and facilitate learning in concrete, experiential ways. This paper explores several key issues in statistical instruction: the need for statistical literacy, the current state of statistical education, course goals and objectives, expected student competencies, essential topics, instructional approaches, and the use of computers and expert systems. Instructional strategies that provide for an epistemological pluralism and accept the validity of multiple ways of knowing and thinking are recommended. Instructor qualifications and characteristics, "hands-on" learning activities, cooperative learning groups, student involvement in research activities, and alternate approaches to testing and assessment are presented as vehicles for accomplishing this objective. Tables in the appendix present research findings related to teaching techniques and essential topics in introductory-level statistics and research methods courses. Contains 67 references. (Author)

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Strategies for Developing and Delivering Effective Introductory-level Statistics and Methodology Courses

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Abstract

Though statistical literacy is an essential skill in our modern society, students often approach statistics courses with apprehension and "mathophobia". Educa. ,rs need to design and deliver statistics instruction so as to counter these anxieties and facilitate learning in concrete experiential ways. This paper explores several key issues in statistical instruction: the need for statistical literacy, the current state of statistical education, course goals and objectives, expected student competencies, essential topics, instructional approaches, and the use of computers and expert systems. Instructional strategies that provide for an epistemological pluralism and accept the validity of multiple ways of knowing and thinking are recommended. Instructor qualifications and characteristics, "hands-on" learning activities, cooperative learning groups, student involvement in research activities, and alternate approaches to testing and assessment are presented as vehicles for accomplishing this objective. Tables in the appendix present research findings related to teaching techniques and essential topics in introductory-level statistics and research methods courses.

Introduction

In our complex society, statistical literacy is an essential skill. Unfortunately, our popular and technical cultures have constructed statistics as "the ultimate embodiment of the abstract and formal" (Turkle & Papert, 1990, p. 128) so most students approach statistics with apprehension or "mathophobia". Educators need to develop instructional approaches to counter such anxieties and facilitate learning in concrete experiential ways (Papert, 1980, 1984). This paper explores five key issues in statistical instruction: the need for statistical literacy, the current state of statistical education, course objectives and topics, instructional approaches, and the use of computers and expert systems.

Statistical Literacy

Statistical Literacy as an Essential Skill

Statistical literacy is an essential skill in our modern society. In times of public election, television, radio, and newspaper reports highlight the results of each new opinion poll. Support for each candidate is identified as representing a certain percentage of the electorate plus or minus some percentage points nineteen times out of twenty. In Canada, a massive Crown corporation (i.e., Statistics Canada) exists for the sole purpose of tracking and trending statistical patterns related to almost every area of life. Even information as "commonplace" as the daily weather forecast is a probabilistic statement based on statistical trends. Almost fifteen years age, Pereia-Mednoza and Swift (1981) recognized a need for statistical literacy and suggested that "individuals need a knowledge of statistics and probability to function in our society" (p. 2).

Statistical Literacy as a Way of Thinking

Statistical literacy is more than an understanding of numbers or probabilities, it also involves a way of thinking (Papert, 1980). In our complex society, we are no longer able to make simple dogmatic or absolutist statements. We recognize that most phenomena are influenced by an intricate web of factors: seen and unseen, direct and indirect. Truth claims are tentative hypotheses, couched in the language of probability and qualification, and subject to critical evaluation and refinement. Falk and Konold (1992) argue that "in our statistical age, public discourse is cast in the language of statistics and probability" and "although our private musings and observations may still be subject to the old deterministic habits of thought ... the teaching of probability should strive not only to provide students with a framework necessary for carrying on such a public discourse, but also to transform their private 'musings'" (p. 152). Statistical literacy enables individuals to understand and evaluate propositional positivistic arguments and to critique the methodological and epistemological premises that underlie such truth claims.

The Current State of Statistical Education

With the exponential increase in knowledge in almost every discipline, the ability to understand, interpret, and critically evaluate research findings is becoming an essential core skill. Buche and Glover (1988) argue that even students interested in becoming practitioners need to be able to comprehend, appreciate, and apply research. Sadly, deficiencies in course design and delivery often hinder the realization of this ideal.

Aiken, West, Sechrist and Reno (1990) have raised concerns about instructor qualifications, course content, and student competencies in existing statistics and methodology courses. In a survey of 186 of 222 psychology departments in North America granting Ph.D. degrees, Aiken, West, Sechrist and Reno (1990) found a median of 2.6 full-time faculty taught statistics and /or measurement at the graduate level. One-third of all programs had no faculty trained in this area, and the median of faculty trained to teach in this area was .9 . Course coverage was often up to 20 years out-of-date, focusing on techniques such as ANOVA, contrasts and comparisons, and regression, and neglecting multivariate analysis, power analysis, and causal modeling. Only one-quarter of recent graduates were judged competent in applying classical test theory concepts such as reliability, validity and item analysis, and less than 10% were competent in applying item response theory, generalizeability theory, and item bias analysis. In a survey of small American colleges, Grosof and Sardy (1990) found statistics was usually a service course taught under convenient labels by instructors without statistical qualifications.

Student statistical anxiety and poor performance in statistics courses are also critical concerns. Hudak and Anderson (1990) found that one of the most disconcerting aspects of teaching undergraduate statistics courses was the appearance of a bimodal distribution of grades whereby some grasped the material with relative ease while others struggled to understand. Mittag (1993) reported that some students describe statistics as their most difficult course and many fear it. Schacht and Stewart (1990) reported that statistics was the most anxiety-producing course in the Sociology department, and that "the feelings of fear and failure associated with math anxiety are largely responsible for the negative learning environment" (p. 53). "Mathophobia" is a very real problem for many students, and instructors need to develop creative and practical ways of relieving this anxiety and making statistics relevant to the student's life-world (Papert, 1980). Hogg (1992) suggests the following problems are major contributors to student "mathophobia" and poor performance in statistics classes:

- statistics teaching is often stagnant, and statistics teachers resist change
- techniques are often taught in isolation, and the absence of connection with the real-world causes students to perceive statistics as irrelevant
- statistics is often presented as a branch of mathematics, and good statistics is equated with rigor or purity rather than careful thinking
- teachers are often unimaginative in methods of delivery, and rely almost exclusively on traditional lecture and discussion approaches
- teachers often construct the statistics course for their own (not the students') satisfaction
- many teachers have inadequate backgrounds in subject knowledge, and lack both experience in applying techniques and the ability to communicate in "plain English"
- statisticians may put their subject in a bad light. Iverson (1992) warns that mathematicians often focus on probability and ignore applied statistics, and "statistics in a mathematical context becomes a set of theorems and proofs together with formulas for the computations of parameter estimates" (p. 39).
- statistics notation in unnecessarily complex and inconsistent

Course Objectives and Topics

To address these deficiencies and develop more effective instructional approaches, educators must first clarify course goals and objectives, expected student skills and competencies, and essential topics in statistical instruction.

Goals and Objectives

Hogg (1992) conducted a participatory research project with students and developed following goal statement for an introductory statistics course:

> "our aim in a first course is to develop critical reasoning skills necessary to understanding our quantitative world. The focus of the course is the process of learning how to ask appropriate questions, how to collect data effectively, how to summarize and interpret that information, and how to understand the limitations of statistical inferences" (p. 8).

Schaeffer (1990) echoes this emphasis on critical reasoning, practical competencies, and interpretive skills, and suggests "the introductory course should prepare students to be logical problem-solvers, guide them through a variety of exploratory techniques, and provide them with a basic understanding of how confirmatory techniques work so that they have some perspective on what statistics can do and what it cannot do" (p. 70). Moore (1992) suggests statistics be viewed as a liberal art that focuses on evaluation and interpretation, and on concepts rather than technical expertise. Brogan and Kutner (1985) believe a reasonable goal for a one semester graduate course is to learn underlying concepts of the scientific method, common research designs and fallacies in the discipline, and elementary statistical techniques.

Blalock (1987) provides the following list of general goals for a statistics course:

- Overcoming fears, resistance and overmemorization by enabling students to overcome anxiety and develop study habits that focus on thinking problems through rather than rapid reading and memorization.
- Stressing the importance of intellectual honesty and integrity, such as making assumptions explicit. "Models required by statistical research are idealized abstractions that can only be approximated in actual research. Intellectual honesty requires that one make careful efforts to assess the nature of these approximations and to lay out the defects in the data and analysis, so that they are in plain view of the potential critic" (p. 167).
- Helping students understand the relationship between deductive and inductive reasoning. Practically, this includes probability theory, understanding causation, and recognition of rules and assumptions in analysis.
- Developing an ability to play the role of reasonable critic. Students need to understand that all research involves trade-offs and that decisions are made with an eye to calculable risks of error.
- Developing the ability to handle complexities systematically. Since theoretical assumptions are always necessary to interpret data, the stronger the theoretical foundation the less ambiguous one's empirical conclusions.

Iverson (1992) argues an introductory course must not only expose students to central concepts and demonstrate the application of techniques, but also enable students to conduct their own research. Hartley, Fisher, and Hartley (1988) suggest students need not only the science of methodology and technique, but the art of making practical research decisions regarding issues such as design and sample size. Allen, Efird, and Eliasziw (1990) also emphasize practical outcomes, and suggest students need to learn how to interpret research results, formulate questions from a data set, solve real-world problems, and learn formal writing skills. However, Chamberlain (1988) cautions that although experiential and practical research-oriented goals are important, "students must do more than engage in the activities and understand their effects. They also need to understand the general principles underlying the activities and be able to apply them to new situations" (p. 109).

Skills and Competencies

Effective statistical instruction must identify the practical skill and competency outcomes students are expected to develop. Anderson and Loynes (1986, pp. 317-318) identified a set of practical competencies they believe are characteristic of the statistically literate, the technically competent statistical analyst, and the full-fledged statistician. According to their evaluation, the statistically literate should be able to:

- Appreciate the ethical position of a statistician.
- Determine the aims of an investigation.
- Translate general aims into specific and realistic problems.
- Recognize situations which call for checks or controls on the quality of data, and construct suitable procedures for checks.
- Organize work (e.g., data collection) effectively.
- Recognize the limitations of one's knowledge.

- Find and read, critically, other relevant material, both in Statistics and in the subject area of the investigation.
- Interpret and/or utilize the results of an analysis.

Technically competent statistical analysts should be able to:

- Recognize which techniques are valid and/or appropriate.
- Apply any techniques necessary, interpret the results, and draw valid conclusions (i.e., comprehension and computing skills).
- Find and use the main sources of published data.
- Understand and use previously unfamiliar techniques.

Full-fledged professional statisticians should be able to:

- Appreciate that real data will have imperfections and react sensibly to difficulties.
- Recognize the various levels of sophistication of techniques of analysis appropriate for data of different reliability.
- Choose an appropriate plan or design for an investigation.
- Build models and develop new methods.

Essential Topics

Effective statistical instruction also needs to focus on the domain knowledge or topics that are most critical. Hogg (1992) developed a list of what he considered were essential topics for an introductory statistics course (see Appendix: Table 1). Mittag (1993) used a Delphi procedure with a panel of twenty-nine experts in Statistics education to develop a list of essential topics for an introductory non-calculus-based college-level statistics course (see Appendix: Table 2). Lopez and Mertens (1994) surveyed 71 members of an American Educational Research Association (A.E.R.A.) Special Interest Group (S.I.G.) on educational research and identified recommended mathematical topics for a one-year college preparatory non-calculus-based Statistics course (see Appendix: Table 3). Giesbrecht, Sell, Scialfa, Sandals, and Ehlers (1994) surveyed instructors of first-level statistics courses at the University of Calgary regarding statistical topic importance and inclusion in current course content (see Appendix: Table 4). According to Mittag (1993), Lopez and Mertens (1994) and Giesbrecht, Sell, Scialfa, Sandals, and Ehlers (1994), the least important topic areas are Analysis of Variance and Non-Parametric Tests, and the most important topic areas include:

- Summarizing Data and Graphs (e.g., frequency histograms, box plots)
- Summarizing Numerical Data (e.g., measures of center and dispersion)
- Probability and Probability Distributions (e.g., normal and binomial distributions, independent and dependent events)
- Estimation (e.g., confidence intervals)
- Hypothesis Testing (e.g., Type I and Type II errors, tests of means)
- Correlation and Regression (e.g., correlation vs. causation, Pearson's correlation coefficient).

Lopez and Mertens (1994), and Giesbrecht, Sell, Scialfa, Sandals, and Ehlers (1994) also surveyed the perceived importance of research methodology topics (see Appendix: Table 5 and 6, respectively). Lopez and Mertens (1994) reported that the most important methodological topics were: Internal validity of research, Developing a research plan, External validity of research, Experimental / quasi-experimental research, and Formulating a hypothesis; and the least important topics were: Feminist epistemology, and Feminist approaches to research. Giesbrecht, Sell, Scialfa, Sandals, and Ehlers (1994) found the most important research topics were: Theories and Hypotheses, Report and Manuscript Writing, and Control and Randomization; and the least important topic was Questionnaire and Scale Development.

Instructional Approaches

Papert (1980) argues that every individual is an epistemologist and that "intellectual structures are built by the learner rather than being taught by a teacher" (p. 19). As such, we need to create learning environments or "microworlds" where students can explore new concepts in concrete experiential ways, develop transitional theories about these new objects and concepts, and integrate or assimilate (Piaget, 1929, 1950) these ideas into their existing mental schemas. Our instructional approaches need to provide for an epistemological pluralism (Turkle & Papert, 1990, 1992, 1993) that accepts "the validity of multiple ways of knowing and thinking" (1990, p. 129). Moore (1992a, 1992b, 1993) argues that students bring a complex mix of intuition and experience to the classroom, and educators need to help students to reconstruct their understanding in ways that integrate new concepts with these pre-existing views of the world. Passive instruction, rooted in the goal of knowledge transfer and the lecture approach, results in students who have a formal knowledge of facts and procedures divorced from intuition and knowledge of other subjects. Students thus indoctrinated cannot solve problems formulated in unfamiliar ways or apply facts to higher order tasks, and their comprehension of the material is algorithmic rather than conceptual. Instruction must focus on "concepts rather than formulae, on underlying models and assumptions rather than specific tests and mechanics of implementation" (Arney, 1979, p. 176). Instruction is also more effective when the course is exciting, personally involving, and oriented to experiential learning (Chamberlain, 1988). When learning takes the form of discovery, students are better able to build connections between new concepts and past knowledge, and organize concepts into relevant and readily-accessible mental schemas.

Schaeffer (1990) provides a list of guidelines, developed by the Center for Statistical Education of the American Statistical Association (A.S.A.), for improving statistics instruction. These guidelines include the following:

- student experiences should focus on asking questions about something in their environment and then finding quantitative ways to answer the question
- problems should be approached in multiple ways with emphasis on discussion and evaluation of various methods
- real data should be used whenever possible, and students should make classroom presentations
- traditional statistics topics should not be taught until students have worked with simple counting and graphing techniques
- the emphasis should be on building intuition not on probability paradoxes or using statistics to deceive
- projects should be an integral part of the course

- statistics should not be taught as a separate unit but introduced to illustrate and expand on concepts and form interdisciplinary links
- progression should be from the concrete to pictorial to abstract
- computers should be utilized.

Instructor Qualifications and Characteristics

An early pioneer in the field of modern statistics, Hotelling (1940), suggested that statistics instructors need to have a thorough knowledge of the area, be familiar with recent advances, have a critical knowledge of statistical theory research, and have an ongoing involvement in both individual and collaborative research. Though statistical expertise and theoretical knowledge are still important prerequisites, instructors of today also need effective pedagogical skills. For example, instructors need to understand the characteristics of their students so that they can make the material relevant to the student's life-world (Bessant, 1992). Arney (1979) remarks that "most students perform poorly not for innate lack of ability, but because they have no foreseeable reason for learning what the professor is trying to teach" (p. 126). Professors must avoid the motivational hazards of allowing students to remain dispassionate or even hostile to the subject matter.

Professors must also integrate both conceptual understanding and practical application into their instruction. Iverson (1992) observes that many professors reflect a bias towards either mathematical theory or applied technique, and that an unbalanced approach negatively impacts statistical instruction. Practitioners may teach in a cookbook fashion, and mathematicians may focus on probability and mathematical theorems and neglect practical applications. Box (1976) suggests this bias results in students being indoctrinated into either "cookbookery" or "mathematistry". "Cookbookery" reflects "a tendency to force all problems into the molds of one or two routine techniques, (with) insufficient thought being given to the real objectives of the investigation or to the relevance of the assumptions implied by the imposed methods" and "mathematistry is characterized by development of theory for theory's sake, which, since it seldom touches down with practice, has a tendency to redefine the problem rather than solve it" (p. 797).

Instructional Techniques

Lopez and Mertens (1994) surveyed 71 members of an American Educational Research Association (A.E.R.A.) Special Interest Group (S.I.G.) on the most common teaching techniques utilized in their statistical courses (see Appendix: Table 7). They found the five most frequently employed teaching techniques were: lecture, discussion, in-class exams, visual presentations, research article critiques; and the five least frequently used techniques were: games, role-playing, reflective writing, alternate assessment, and take-home exams. Though the lecture is the most commonly used instructional technique, it "emphasizes some of the student-based obstacles contributing to poor performance: high levels of math anxiety, low self-confidence, passivity, fear, and even hostility" (Bessant, 1992, p. 144). Paas (1992) quotes a plethora of studies that suggests that in the empirical and formal sciences (e.g., math, statistics, physics, and computer science), traditional instructional methods such as lectures are not effective learning devices. Instead, instructors should focus on concrete, experiential and discovery-oriented techniques (Papert, 1980) such as "hands-on" learning activities, cooperative learning groups, student involvement in research activities, and alternate testing and assessment procedures. Computers and computer expert systems can also serve as powerful tools in helping students build new mental representations of statistical concepts (Papert, 1980).

"Hands-on" Learning Activities. Turkle and Papert (1990) suggest that we need to use "concrete and personal approaches to knowledge that are far from the cultural stereotypes of formal mathematics" (p. 128) and that a closeness to objects provides a concrete experiential way of exploring formal concepts. Hettich (1988) and Jacobs (1988, 1992) suggest that data analysis becomes more real when students generate data themselves (e.g., student gender, age, height). This approach produces data that is not contrived but has the characteristics of actual data (e.g., occasional ambiguity and complexity). Students can ponder why so-called normal distributed variables (e.g., height) produce skewed distributions for some groups. Instructors can also explore how student-generated data, such as likes or dislikes about university life, can be transformed into research questions and testable hypotheses.

Schacht and Stewart (1990) suggest instructors use interactive, attention-getting teaching techniques that require some sort of response from students. This response can range from providing descriptive data (e.g., height), to expressing an opinion, to complex problem-solving. Such an approach "triggers an intrinsic interest in the results of statistical calculations and procedures because the students' opinions and behaviors 'are' the data ... (and) because the students are the data, the process of calculating different statistical formulas is demystified; this demystification reduces statistical anxieties dramatically" (p. 329). Lock and Moore (1992) suggest "low-tech" objects such as coins, dice or cards attract attention and make concepts such as probability concrete and relevant. Beins (1988) asked students to write companies who made research-based advertising claims. He found this made collecting and interpreting data more interesting, helped students understand how research design and statistics are used in real-life situations, and helped them make discerning judgments about advertiser's claims based on research data.

Thompson (1994) suggests that increasing the realism of data helps students learn firsthand that data analysis is an integral part of the research process. Singer and Willet (1992) believe real data increases motivation because it is more authentic, interesting and relevant to students. However, Willet and Singer (1992) warn that not all real data sets are effective tools. They suggest that the instructional suitability of data sets is based on eight criteria: the importance of using raw data (vs. summarized), data authenticity (i.e., real measurements on real samples), the availability of background information (e.g., source of data, measurement techniques, variable definitions), the availability of case-identifying information (e.g., demographics), the intrinsic appeal and relevance of the data set (e.g., topical or controversial subjects), and their suitability for a variety of statistical analyses.

Cooperative Learning Groups. Brothen (1991) reports that students learn better in active cooperative learning groups and take greater responsibility for their own learning and interaction. Moore (1992, 1993) suggest the teacher's role should be that of consultant and moderator rather than "presenter of information". The instructors' role is to shape the environment for learning by setting tasks which encourage open discussion and group problem-solving. Cumming (1988) explored the effects of streaming, or forming cooperative learning groups of students with similar ability, on statistical learning and performance. Though past research had shown that students benefit from streamed groups, Cummings (1988) discovered that students suffered if they were placed in groups of lower ability or expectation and that most students preferred mixed groups and performed equally as well in mixed groups as in streamed groups.

Student Involvement in Research Activities. Student research activities can help promote the understanding and application of concepts and the development of practical research skills through "hands-on" experience. Carsrud (1988) reports a highly-successful research apprenticeship program where undergraduate students are involved in research activities under the supervision of advanced graduate students. Undergraduate participants in the program appreciated the individual attention they received from their graduate supervisors and reported the program increased their motivation to learn research skills. Goodman (1980) reports a successful undergraduate research program by Margaret F. Washburn, the first woman Ph.D. in psychology. She involved students in research activities that resulted in 69 published studies with 119 undergraduates as joint authors. In an undergraduate statistics course in Brazil, Peres and Morettin (1985) utilized a cooperative experiential approach whereby students engaged in consulting and data analysis, and produced oral presentations and written reports for clients in business and industry. Palladino, Carsrud, Hulicka, and Benjamin (1988) recommend that better undergraduate students be given the opportunity to generate a research problem and design, implement the project (including funding), write the report, and present a report of the completed research to others. Such research need not be highly original, but may be a replication of a classic study. Yoder (1988) suggests that having students replicate a published study helps them learn how to design, conduct, analyze, interpret, and report a research study. Chamberlain (1988) suggests that students develop the following skills prior to conducting research: competence in using library resources, ability to critically read and understand research literature and respond to its content, familiarity and knowledge of how to deal with ethical issues, ability to translate research questions into designs, and related skills such as computer literacy, effective writing, preparation of research proposals, and presentation of research findings.

Alternate Approaches to Testing and Assessment. Eltinge (1992) suggests poor student performance is often the result of an inadequate preparation in mathematical and logical concepts which form the basis of statistical reasoning, and recommends using diagnostic pre-tests to ensure students have a minimum level of competence. However, Papert (1980) believes the existing "technology of grading" is counter-productive and that a perpetual learning of "prerequisites" dissociates students from truly powerful ideas. An alternative solution is to change testing policies and procedures so that students can grapple with new statistical ideas without fear of failure.

Davidson, House, and Boyd (1984) recommend using a retest policy to help reduce test anxiety, clarify course evaluation standards, and guide the relearning of previously-tested material. Friedman (1987) implemented such an approach in response to two ongoing problems he encountered: i.e., that most students found introductory statistics courses anxiety-provoked, and that less capable students tended to fall increasingly behind as the course progressed. Friedman's (1987) approach incorporated regular multiple-choice exams following a lecture session, optional lab sessions where the multiple-choice exams were reviewed, open-book exams, and the opportunity for students to repeat an exam (with a small penalty). Students feedback indicated that the repeat exam procedure improved their chances for a higher grade, led to better learning, kept them from falling behind, and decreased test and statistics anxiety. Nearly all students took one or more repeat exams, and 92% of repeat exams resulted in higher grades reflecting an average increase of 17 points (i.e., just over one letter grade). Only 44% of the students believed the retest policy helped weaker students more than good students and only 47% believed it required more work on their part. Students also reported they studied as much for the repeat exam as for the original exam.

Computers and Expert Systems.

Turkle and Papert (1990) suggest that although the conventional route into formal systems thought is through abstract symbols, computer graphics provide individuals with concrete learning styles entry through the display of movement, intuition, and visual impression. A computational object is "on the border between an abstract idea and a concrete physical object ... (and although it) can be defined by the most formal of rules and is us a mathematical construct ... it is visible, almost tangible, and allows a sense of direct manipulation that only the encultured mathematician can feel in traditional formal systems. The computer has a theorctical vocation: it can make the abstract concrete; it can bring formality down-to-earth" (p. 131). Papert (1980, 1984) argues the advantage the computer offers is not a new technological way of delivering instruction, but the provision of an "object-to-think-with" (p. 23). Papert and colleagues (e.g., Brandes & Wilensky, 1991; Papert, 1980) effectively demonstrated how the LOGO programming language and a robotic "turtle" could create an environment where children could experientially explore and construct understandings of computers and mathematics. Computer-based simulations (e.g., Benedict & Butts, 1988; Krieger & Pinter-Lucke, 1992) can also provide "microworlds" that serve as incubators for powerful ideas, allow learners to invent personal set of assumptions about the microworld and its laws, and enable students to construct and test transitional theories.

Computers can also be used to explore how learners process information and construct knowledge. In an interesting implementation of this concept, Ford and Ford (1992) provided students with a computer "expert-system interface" where they could use everyday language to communicate (unknowingly) with a human expert. This approach provided students with access to an unrestricted knowledgeable system that interacted in natural languag·, responded to their lead, and allowed them to build knowledge in an individual way rather than from pre-structured patterns. Ford and Ford (1992) identified two routes to success: the first path was a relatively passive intake of information coupled with an attention to low-level procedural detail (primarily associated with female students) and the second path involved an active focus on conceptual material. Ford and Ford (1992) suggest the first group were operation learners (Pask, 1976) who concentrate on procedural detail and take a serialistic passive learning approach focused on low-level detail; and the second group were comprehension learners (Pask, 1976) who use an active holistic learning strategy focused on information high in the subject hierarchy. However, Turkle and Papert (1990, 1992, 1993) might argue that such labels reflect a "supervaluation of the formal approach" (p. 133) of abstract, logical thought, and that an operational learning style reflects a preference for negotiating new theoretical understanding in relationship with concrete contextualized detail.

Jacobs (1992) suggest that interactive computer technologies can spearhead a move to teachers as facilitators rather than purveyors of information. Multimedia and hypermedia tools (e.g., Chromiak & Rossman, 1992; Halavin & Sommer, 1990) can provide a web of interconnected knowledge that enables individuals to learn in a non-sequential way through discovery and experience (Schwier, 1993). Nelson and Palumboa (1992) argue that hypermedia and neural networks parallel human memory processes and serve as useful tools for organizing and modeling knowledge. Learning involves "the reorganization of knowledge in a structured associative network that allows (one) to combine ideas, extrapolate, and infer ... (structural networks) are composed of both the stored information and the relational links that interconnect the information ... (and so facilitate) connecting new material within one's preexisting knowledge structure" (p. 288-289).

Current technological research is also exploring how statistical expert systems (e.g., Sandals & Pyryt, 1994), which capture the domain knowledge and reasoning processes of statistical experts in a computer database, can facilitate learning (Saleem & Azad, 1992; Sandals & Pyryt, 1992, 1993). Research indicates that experts not only possess greater domain knowledge than novices, but also have more powerful mental representations and more effective problem-solving strategies (e.g., Chi & Glaser, 1984; Ennis & Safrit, 1991; Larkin, 1983). Hong and O'Neil (1992) explored the mental representations of statistical experts, and concluded that teaching concepts prior to procedures and using diagrammatic representations would help learners build relevant mental models of statistical concepts. They found such an approach resulted in knowledge structures that were more accessible (i.e., students were more aware of their own knowledge), functional (i.e., it allowed them to predict or explain what would happen in problem situations), and improveable (i.e., they could pay more attention to acquiring or inventing knowledge or skills).

Jonassen, Wilson, Wang, and Grabinger (1993) recommend that future expert systems explore constructivist ways of helping learners build their own models or representation of knowledge. They suggest that many existing expert systems "while useful and productive of learning, supplant much of the cognitive processing in the user or learner and impose a model of thinking that requires learners to replicate that model in their own thinking ... expert systems best support learning, not as models of thinking to emulate, but rather as formalisms for representing the knowledge of learners or as tools for modeling the content that is being studied in a causal manner. When learners create expert systems to represent their own thinking or to represent the casual logic in a content domain, they are processing content at a deeper level and constructing knowledge that is more meaningful to them" (p. 86).

Conclusion

Statistical literacy, as both a skill and a way of thinking, is an essential skill in our complex modern society. Unfortunately, many students approach the study with a "mathophobia" that is rooted in the image of statistics as an abstract, esoteric, and obtuse form of logic divorced from real life. To counter such anxieties, educators need to build connections between statistics and life, and use instructional approaches that allow for experiential discovery-oriented explorations of theoretical concepts using concrete objects. "Hands-on" learning activities, cooperative learning groups, and alternate testing and assessment procedures can help facilitate this. Computer technology can also enable educators to model expert knowledge and reasoning processes and create virtual "statistical playgrounds" or "microworlds". Such environments can help learners build an intuitive understanding of fundamental concepts and develop practical skills and competencies that enable them to conduct their own research.

References

Aiken, L.S., West, S.G., Sechrest, L., & Reno, R.R. (1990). Graduate training in statistics, methodology, and measurement in psychology. American Psychologist, 45, 721-727.

Allen, R., Efird, J., & Eliasziw, M. (1990). A symposium in statistical education for the future. American Statistical Association 1990 Proceedings of tne section on statistical education (pp. 84-89). Alexandria, VA: American Statistical Association.

Arney, W. R. (1979). Statistics as language. Teaching Sociology, 6, 173-177.

Beins, B. (1988). Teaching the relevance of statistics through consumer-oriented research. In M. E. Ware & C. L. Brewer, Handbook for teaching statistics and research methods (pp. 5-6). Hillsdale, NJ: Lawrence Erlbaum Associates.

Benedict, J. O., & Butts, B. D. (1988). Computer simulation or real experimentation: Is one better for teaching experimental design ? In M. E. Ware & C. L. Brewer, Handbook for teaching statistics and research methods (pp. 177-179). Hillsdale, NJ: Lawrence Erlbaum Associates.

Bessant, K. C. (1992). Instructional design and the development of statistical literacy. Teaching Sociology, 20, 143-149.

Blalock, H. M. (1987). Some general goals in teaching statistics. Teaching Sociology, 15, 164-172.

Brandes, A., & Wilensky, U. (1991). Treasureworld: A computer environment for the study and exploration of feedback. In I. Harel & S. Papert (Eds.), Constructionism (pp. 391-415). Norwood, NJ: Ablex Publishing Corporation.

Brogan, D., & Kutner, M. (1985). Graduate service statistics courses: What, to whom, and by whom ? American Statistical Association 1985 Proceedings of the section on statistical education (pp. 143-145).

Brothen, T. (1991). Implementing a computer-assisted cooperative learning model for introductory psychology. Teaching of Psychology, 18(3), 183-185

Box, G. E. P. (1976). Science and statistics. Journal of the American Statistical Society, 71, 791-799.

Buche, D. D., & Glover, J. A. (1988). Teaching students to review research as an aid for problem solving. In M. E. Ware & C. L. Brewer, Handbook for teaching statistics and research methods (pp. 126-129). Hillsdale, NJ: Lawrence Erlbaum Associates.

Carsrud, A. L. (1988). Graduate student supervision of undergraduate research: Increasing research opportunities. In M. E. Ware & C. L. Brewer, Handbook for teaching statistics and research methods (pp. 197-200). Hillsdale, NJ: Lawrence Erlbaum Associates.

Chamberlain, K. (1988). Teaching the practical research course. In M. E. Ware & C. L. Brewer, Handbook for teaching statistics and research methods (pp. 106-110). Hillsdale, NJ: Lawrence Erlbaum Associates.

Chi, M. T. M., & Glaser, R. (1984). Problem solving abilities. In R. Sternberg (Ed.), Human abilities: An information processing approach (pp. 227-250). San Francisco: Freeman.)

Chromiak, W., & Rossman, A. (1992). Using HyperCard to teach statistics. In F. Gordon & S. Gordon (Eds.), Statistics for the twenty-first century (MAA Notes, No. 26) (pp. 243-257). Washington, DC: Mathematical Association of America.

Cumming, G. (1988). The introductory statistics course: Mixed student groups preferred to streamed. In M. E. Ware & C. L. Brewer, Handbook for teaching statistics and research methods (pp. 9-12). Hillsdale, NJ: Lawrence Erlbaum Associates.

Davidson, W. B., House, W. J., & Boyd, T. L. (1984). A test-retest policy for introductory psychology courses. Teaching of Psychology, 11, 182-184

Eltinge, E. M. (1992). Diagnostic testing for introductory statistics courses. In F. Gordon & S. Gordon (Eds.), Statistics for the twenty-first century (MAA Notes, No. 26) (pp. 56-65). Washington, DC: Mathematical Association of America

Ennis, C. D., & Safrit, M. J. (1991). Using a computer simulation to compare expert/novice problem-solving routines. British Journal of Educational Technology, 22(3), 174-186.

Falk, R., & Konold, C. (1992). The psychology of learning probability. In F. Gordon & S. Gordon (Eds.), Statistics for the twenty-first century (MAA Notes, No. 26) (pp. 151-164). Washington, DC: Mathematical Association of America.

Ford, N., & Ford, R. (1992). Learning strategies in an 'ideal' computer-based learning environment. British Journal of Educational Technology, 23(3), 195-211.

Friedman, H. (1987). Repeat examinations in introductory statistics courses. Teaching of Psychology, 14(1), 20-23.

Giesbrecht, N., Sell, Y., Scialfa, C., Sandals, L., & Ehlers, P. (1995). A study of the feasibility of an across-university course in Statistics and Methodology. Unpublished manuscript. University of Calgary.

Goodman, E. S. (1980). Margaret F. Washburn (1871-1939): First woman Ph.D. in psychology. Psychology of Women Quarterly, 5, 69-80.

Halavin, J., & Sommer, C. (1990). Using hypertext to develop an algorithmic approach to teaching statistics. In 1990 Proceedings of the Section on Statistical Education (pp. 118-122). Alexandria, VA: American Statistical Association.

Hartley, A. A., Fisher, L. A., & Hartley, J. T. (1988). Teaching the arts of psychological research. In M. E. Ware & C. L. Brewer, Handbook for teaching statistics and research methods (pp. 173-175). Hillsdale, NJ: Lawrence Erlbaum Associates.

Hettich, P. (1988). The student as data generator. In M. E Ware & C. L. Brewer, Handbook for teaching statistics and research methods (pp. 60-61). Hillsdale, NJ: Lawrence Erlbaum Associates.

Hogg, R. V. (1992). Towards lean and lively courses in statistics. In F. Gordon & S. Gordon (Eds.), Statistics for the twenty-first century (MAA Notes, No. 26) (pp. 3-13). Washington, DC: Mathematical Association of America.

Hotelling, H. (1940). The teaching of statistics. Hanover, N.H.: Address presented at the meting of the Institute of Mathematical Statistics.

Hong, E., & O'Neil, H. F. (1992). Instructional strategies to help learners build relevant mental models in inferential statistics. Journal of Educational Psychology, 84(2), 150-159.

Hudak, M. A., & Anderson, D. E. (1990). Formal operations and learning style predict success in statistics and computer science courses. Teaching of Psychology, 17(4), 231-234.

Iverson, G. R. (1992). Mathematics and statistics: An uneasy marriage. In F. Gordon & S. Gordon (Eds.), Statistics for the twenty-first century (MAA Notes, No. 26) (pp. 20-44). Washington, DC: Mathematical Association of America.

Jacobs, K. W. (1988). Instructional techniques in the introductory statistics course: The first class meeting. In M. E. Ware & C. L. Brewer, Handbook for teaching statistics and research methods (p. 4). Hillsdale, NJ: Lawrence Erlbaum Associates.

Jacobs, G. (1992). Hypermedia and discovery-based learning: A historical perspective. British Journal of Educational Technology, 23(2), 113-121.

Jonassen, D. H., Wilson, B. G., Wang, S., & Grabinger, R. S. (1993). Constructivist uses of expert systems to support learning. Journal of Computer-Based Instruction, 20(3), 86-94.

Krieger, H., & Pinter-Lucke, J. (1992). Computer graphics and simulations in teaching statistics. In F. Gordon & S. Gordon (Eds.), Statistics for the twenty-first century (MAA Notes, No. 26) (pp. 198-206). Washington, DC: Mathematical Association of America.

Larkin, J. H. (1983). The role of problem representation in physics. In D. Getner & A. L. Stevens (Eds.), Mental models (pp. 75-98). Hillsdale, NJ: Erlbaum.

Lock, R. H., & Moore, T. L. (1992). Low-tech ideas of teaching statistics. In F. Gordon & S. Gordon (Eds.), Statistics for the twenty-first century (MAA Notes, No. 26) (pp. 99-108). Washington, DC: Mathematical Association of America

Lopez, S. D., & Mertens, D. M. (1994). Survey of the SIG: Professors of educational research teaching practices 1992-93. . In M. E. Ware & C. L. Brewer, Handbook for teaching statistics and research methods . Hillsdale, NJ: Lawrence Erlbaum Associates.

Mittag, K. C. (1993). A delphi study to determine standards for essential topics and suggested instructional approaches for an introductory non-calculus-based college-level statistics course. Unpublished doctoral dissertation. Texas A&M University.

Moore, D. S. (1992). Teaching statistics as a respectable subject. In F. Gordon & S. Gordon (Eds.), Statistics for the twenty-first century (MAA Notes, No. 26) (pp. 14-25). Washington, DC: Mathematical Association of America.

Moore, D. S. (1993). The place of video in new styles of teaching and learning statistics. The American Statistician, 47(3), 172-176.

Nelson, W. A., & Palumboa, D. B. (1992). Learning, instruction, and hypermedia. Journal of Educational Multimedia and Hypermedia, 1, 287-299.

Paas, F. G. W. (1992). Training strategies for attaining transfer of problem-solving skill in statistics: A cognitive-load approach. Journal of Educational Psychology, 84(4), 429-434.

Palladino, J. J., Carsrud, A. L., Hulicka, I. M., & Benjamin, L. T. (1988). Undergraduate research in psychology: Assessment and directions. In M. E. Ware & C.

L. Brewer, Handbook for teaching statistics and research methods (pp. 202-205). Hillsdale, NJ: Lawrence Erlbaum Associates.

Pereia-Mendoza, L., & Swift, J. (1981). Why teach statistics and probability - a rationale. In A. P. Schulte & J. R. Smart (Eds.), Teaching statistics and probabiiity (1981 Yearbook of the National Council of Teachers of Mathematics, pp. 1-7). Reston, VA: National Council of Teachers of Mathematics.

Papert, S. L. (1980). Mindstorms. New York: Basic Books.

Papert, S. (1984). New theories for new learning. School Psychology Review, 13(4), 422-428.

Pask, G. (1976). Styles and strategies of learning. British Journal of Educational Psychology, 51, 345-377.

Peres, C. A., & Morettin, P. A. (1985). Educating and training undergraduate applied statisticians. Journal of Educational Statistics, 10(3), 283-292.

Piaget, (1929). The child's conception of the world. New York: Harcourt, Brace and Co.

Piaget, (1950). The psychology of intelligence. . New York: Harcourt, Brace and Co.

Saleem, N., & Azad, A. N. (1992). Expert systems as a statistics tutor on call. Journal of Computers in Mathematics and Science Teaching, 11, 179-191.

Sandals, L. H., & Pyryt, M. C. (1992). New directions of teaching research methods and statistics: The development of a computer-based expert system. Paper presented at the annual meeting of the American Educational Research Association, San Francisco, CA. April, 1992.

Sandals, L. H., & Pyryt, M. C. (1993). Expert systems and applied intelligent learning systems for research methods and statistics. Paper presented at the 1993 annual meeting of the American Educational Research Association, Atlanta, Georgia.

Sandals, L. H., & Pyryt, M. C. (1994). The statistical Advisor: The validation of a graphically-oriented computer-based statistical decision-making system. Paper presented at the 1994 annual meeting of the American Educational Research Association, New Orleans.

Schacht, S. P., & Stewart, B. J. (1990). Interactive / user-friendly gimmicks for teaching statistics. Teaching Sociology, 329-332.

Schaeffer, R. L. (1990). Toward a more quantitatively literate citizenry. The American Statistician, 44(1), 2-3.

Schaeffer, R. L. (1992). Data, discernment and decisions: An empirical approach to introductory statistics. In F. Gordon & S. Gordon (Eds.), Statistics for the twenty-first century (MAA Notes, No. 26) (pp. 69-82). Washington, DC: Mathematical Association of America.

Schwier. R. A. (1993). learning environments and interaction for emerging technologies: Implications for learner control and practice. Canadian Journal of Educational Communication, 22(3), 163-176.

Singer, J. D., & Willet, J. B. (1990). Improving the teaching of applied statistics: Putting the data back into data analysis. The American Statistician, 44(3), 223-230.

Turkle, S., & Papert, S. (1990). Epistemological pluralism: Styles and voices within the computer culture. Signs, 16(1), 128-157.

Turkle, S., & Papert, S. (1992). Epistemological pluralism and the revaluation of the concrete. Journal of Mathematical Behavior, 11(1), 3-33.

Turkle, S., & Papert, S. (1993). Styles and voices. For the Learning of Mathematics, 13(1), 49-52

Willet, J. B., & Singer, J. D. (1992). Providing a statistical 'model': Teaching applied statistics using real-world data. In F. Gordon & S. Gordon (Eds.), Statistics for the twenty-first century (MAA Notes, No. 26) (pp. 83-98). Washington, DC: Mathematical Association of America.

Yoder, J. (1988). Teaching students to do research. In M. E. Ware & C. L. Brewer, Handbook for teaching statistics and research methods (pp. 103-105). Hillsdale, NJ: Lawrence Erlbaum Associates.

APPENDIX

Table 1.

Important Topics in an Introductory Statistics Course.

Most important

- Recognition that statistics is a part of everyday life. Reported statistics may be incorrect or misused, so it is important that we become critical consumers of media-presented statistics - asking questions about the quality of the data and the reliability of the analysis.
- Understanding factors that influence variability, e.g..: bias, sampling error, systematic error, measurement error, regression effect, etc. Understanding that one needs to detect both the fitted pattern and residual variation in observations.
- Collection and summarization of data, basic exploratory data analysis.
- Graphing.

Second most important

- Sampling and surveys, including the importance of quality data.
- Elementary experimental design, including discussion of ethics and the distinction between observational and experimental investigation.
- Problem formulation and the importance of operational definitions and the process of inquiry (i.e., iterative nature of the scientific method).
- Basic distributions (e.g., normal, binomial) as approximations of data variability.
- Measures of association, such as correlation and regression.

Third most important

- Elementary probability, including event trees and conditional probability.
- The central limit theorem and law of averages.
- Elementary inferences from samples.
- Ability to use statistical software packages.

Fourth most important

- Understanding outliers and how statistical measures are influenced by data.
- Statistical significance vs. practical significance.
- Categorical data and contingency tables.
- Simulation.

Source: Adapted from Hogg, R. V. (1992), p. 10.

Table 2.

Consensus List of Topics for an Introductory Non-Calculus-Based College-Level Statistics Course

1. Data Collection
    1. Importance of randomization
    2. Sample vs. experiment as data source
    3. Types of data
    4. Measurement
    5. Context of data
2. Summarizing Data (Graphs)
    1. Bivariate plotting techniques
    2. Regression lines
    3. Box plots
    4. Stem-and-leaf plots
    5. Frequency histograms
    6. Relative frequency histograms
    7. Frequency tables
3. Summarizing Data (Numerical)
    1. Measures of dispersion
    2. Measures of center
    3. Population parameters vs. sample statistics
    4. Outliers

5. Shape of data

6. Quartiles

4. Probability Distributions

1. Normal distribution

2. Independent vs. dependent events

3. Expected value

4. Central limit theorem

5. Simulation of possible outcomes

6. Binomial distributions

5. Estimation

1. Effects of sample size

2. Interval estimation and confidence intervals

3. Sampling distributions of statistics

4. Point estimation

6. Experimental Design

1. Variability

2. Randomization

3. Replication

4. Control and experimental groups

5. Response and explanatory variables

6. Bias

7. Confounding variables

7. Hypothesis Testing

   1. Meaning of statistically significant
   2. Introduction to inference
   3. p-values
   4. Type I and Type II errors
   5. Two population tests of means
   6. One population tests of proportion
   7. Paired vs. non-paired t-tests
   8. One population tests of means

8. Categorical Data Analysis

   1. Two way frequency tables
   2. Chi-squared test for independence

9. Correlation and Regression

   1. Interpreting regression equation
   2. Correlation vs. causation
   3. Prediction
   4. Residual analysis
   5. Pearson's correlation coefficient
   6. Standard error

10. Analysis of variance

   1. Purpose of ANOVA

Source: Adapted from Mittag (1993).

Table 3.

Recommended Mathematical Topics

in One Year College Preparatory Non-Calculus-Based Statistics Course.

Topic	% of Sample Rating Topic as Important
Data Collection	
• Sources of data	89 %
• Data types	88 %
• Sampling methods	86 %
• Survey vs. experimental	81 %
• Introduction to statistical inference	66 %
• Importance of randomization	78 %
• Misuse of data	77 %
Numerical Descriptive Statistics	
• Central tendency (mean, median, mode)	98 %
• Dispersion (range, variance, std. dev.)	97 %
• Quartiles	82 %
• Percentiles	83 %
• Outliers	82 %
• Shape of data	84 %
• Contrast population vs. sample	79 %
Graphic Representation	
• Illusions and distortions	78 %

Topic	% of Sample Rating Topic as Important
Graphic Representation (cont'd)	
• Frequency tables	92 %
• Relative frequency tables	88 %
• Frequency histogram	93 %
• Relative frequency histogram	86 %
• Bar chart	71 %
• Stem & leaf plot	72 %
• Scatter plot	83 %
• Regression line	74 %
Probability	
• Sample space	75 %
• Simple vs. compound events	81 %
• Independent vs. dependent events	85 %
• Permutations and combinations	73 %
• Simulation of univariate outcomes	67 %
• Probability rules	82 %
• Conditional probability	77 %
• Expected value	85 %
• Random variables	80 %
• Binomial distributions	84 %
• Central limit theorem	69 %

Topic	% of Sample Rating Topic as Important
Probability (cont'd)	
• Normal distributions	86 %
• Variance	73 %
Experimental Design	
• Comparative experiments (treatment vs. control)	67 %
Estimation	
• Point estimates of parameters	78 %
• Sampling distributions of the mean	90 %
• Confidence intervals	87 %
• Sample size	74 %
• Sampling distribution from a normal distribution	70 %
Hypothesis Testing	
• Testing for population mean equal to a constant	71 %
• Type I and Type II errors	72 %
• Test for equal population means	65 %
• Meaning of statistically significant	79 %
• P-values	65 %
Regression	
• Pearson's correlation coefficient	77 %
• Regression equation	79 %
• Standard error and variance	72 %

Topic	% of Sample Rating Topic as Important
Regression (cont'd)	
• Prediction	69 %
Frequency Tables	
• One way	69 %
• Two way	71 %
• Chi-square test	73 %

Source: Adapted from Lopez and Mertens (1994).

Table 4.

Statistical Topic Importance and Course Coverage

Statistical Topic	Importance		Currently Taught		
Summarizing Data & Graphs					
Frequency histograms	4 6	*	SS	MS	ED
Relative frequency histograms	4.5	*	SS	MS	ED
Bivariate plotting techniques	4.4	*	SS		ED
Regression lines	4.3	*	SS		ED
Box plots	3.9	*	SS	MS	ED
Stem-and-leaf plots	3.3		SS	MS	ED
Pie charts	2.6				
Summarizing Data: Numerical					
Measures of center	4.9	*	SS	MS	ED
Population parameters vs. sample statistics	4 8	*	SS	MS	ED
Measures of dispersion	4.8	*	SS	MS	ED
Characteristics of sample distributions	4.6	*	SS	MS	ED
Outliers	4 3	*	SS	MS	ED
Percentiles	4 1	*	SS	MS	
Coding data	2 6				
Probability and Probability Distributions					
Normal distribution	4.9	*	SS	MS	ED
Expected value	4 8	*	SS	MS	ED
Central limit theorem	4 8	*	SS	MS	ED
Binomial distributions	4.4	*	SS	MS	ED
Mutually exclusive events	4 3	*	SS	MS	ED
Independent events	4 3	*	SS	MS	ED
Combining probabilities	4 1	*	SS	MS	ED

Statistical Topic	Importance		Currently Taught		
Probability and Probability Distributions (cont'd)					
Simulation of possible outcomes	3.9	*	SS	MS	ED
Sample space	3.9	*	SS	MS	ED
Conditional probability	3.8	*	SS	MS	ED
Union-intersection problems	3.4				
Estimation					
Meaning of statistically significant	4.8	*	SS	MS	ED
Interval estimation & confidence intervals	4.7	*	SS	MS	ED
Sampling distribution of statistics	4.7	*	SS	MS	ED
Effects of sample size	4.5	*	SS	MS	ED
Point estimation	4.5	*	SS	MS	ED
Least squares criterion & estimation	4.3	*	SS		ED
Bias & precision of estimation	4.0	*	SS	MS	ED
Hypothesis Testing					
Introduction to inference	4.9	*	SS	MS	ED
p-values	4.7	*	SS	MS	ED
Type I and type II errors	4.7	*	SS	MS	ED
Two population test of means	4.7	*	SS	MS	ED
One vs. two-tailed tests	4.6	*	SS	MS	ED
One population test of means	4.5	*	SS	MS	ED
One population tests of proportion	4.3	*	SS	MS	ED
Paired vs. non-paired t-test	4.1	*	SS	MS	ED
Two population tests of proportion	4.0	*	SS	MS	ED
Power & power analysis	3.5		SS		

Statistical Topic	Importance		Currently Taught		
Categorical Data Analysis					
Chi-squared test for independence	4.4	*	SS	MS	ED
Two way frequency tables	4.1	*	SS	MS	ED
Log linear models	2.2				
Correlation and Regression					
Understanding correlation vs. causation	4.7	*	SS	MS	ED
Simple regression	4.3	*	SS	MS	ED
Pearson's correlation coefficient	4.3	*	SS		ED
Prediction	3.9	*	SS	MS	ED
Standard error of regression coefficients	3.7	*	SS		ED
Residual analysis	3.5	*		MS	ED
Partial correlation	3.0				
Multiple regression	2.9				
Analysis of Variance					
Purpose of ANOVA	4.0	*	SS	MS	ED
One-way between-subjects design	3.9	*	SS	MS	ED
Planned & post-hoc comparisons	3.3		SS		ED
One-way within-subjects design	3.2		SS		
K-way between-subjects design	3.1		SS		ED
Mixed design	2.8		SS		
K-way within-subjects design	2.7				
Trend analysis	2.3				

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Non-Parametric Tests					
Measures of association	3.6	*	SS		ED
Tests based on ranks	3.3		SS	MS	ED
Kolmogorov-Smirnov tests	2.5				
Randomization tests	2.1				

Note: Topics rated as important are marked with an asterisk ('*')

Faculties: SS = Social Science, MS = Math Science, ED = Education

Source: Giesbrecht, Sell, Scialfa, Sandals, and Ehlers (1994).

Table 5.

Research Methods Topic Importance.

Topic	Importance
Internal validity of research	4.2
Developing a research plan	4.1
External validity of research	4.1
Experimental / quasi-experimental research	3.9
Formulating a hypothesis	3.9
Evaluating research reports	3.8
Correlational method of research	3.7
Writing a research report	3.7
Reviewing the literature	3.6
Sample selection techniques	3.5
Objectivity and subjectivity in research	3.5
Ex post facto research	3.5
Reliability and validity of instruments	3.5
Generalizability issues	3.5
Problems in interpreting data	3.4
Measuring instruments	3.4
Inferential statistics	3.3
The scientific method	3.3
Descriptive statistics	3.2

Topic	Importance
Library sources of information	3.2
Bias in research	3.2
The descriptive method of research	3.1
Survey data	3.0
Dilemmas researchers face	3.0
Controversies in research	2.9
Ethics of research	2.7
Observational data	2.3
Positivist epistemology	2.2
Interview data	2.2
Ways of knowing	2.1
Qualitative research	2.1
Evaluation research	2.0
Ethnographic research	1.8
Naturalistic research	1.7
Single subject research	1.6
Naturalistic epistemology	1.6
Cultural issues in research	1.6
Anecdotal data	1.5
Document analysis	1.4
Action research	1.4

Topic	Importance
Careers in research	1.3
Historical method of research	1.2
Gender issues in research	1.2
Interpretive inquiry	1.0
Oral history	.8
Photographs and artifacts in research	.7
Feminist epistemology	.4
Feminist approaches to research	.4

Source: Adapted from Lopez & Mertens (1994).

Table 6.

Research Methods Topic Importance and Course Coverage

	Importance						
Research Methods Topic	SS	MS	ED		Currently Taught		
Philosophies of Science							
Science vs. conventional wisdom	3.9	2.8	4.0		SS		ED
Induction and deduction	4.1	2.3	4.0		SS		ED
Prediction and explanation	4.4	1.8	3.5		SS		ED
Empiricism	3.5	1.8	3.5		SS		ED
Rationalism	3.3	1.3	2.5		SS		
Falsification and Popper	3.2	1.3	2.0		SS		
Phenomenology	3.0	1.3	2.0				
Logical positivism	3.0	1.3	2.0				
Post-modernism	2.9	1.3	2.0				
Theories and Hypotheses							
Null & alternative hypotheses	4.6	4.0	5.0	*	SS	MS	ED
One-tailed & two-tailed hypotheses	4.3	3.6	5.0	*	SS	MS	ED
Hypotheses	4.7	3.6	4.5	*	SS	MS	ED
Developing a testable hypothesis	4.7	3.0	4.5	*	SS		ED
Research hypotheses	4.7	3.0	4.5	*	SS	MS	ED
Statistical hypotheses	4.3	3.2	4.5	*	SS	MS	ED
Theories	4.4	3.0	3.5	*	SS	MS	ED
Laws	3.6	2.8	3.5		SS		ED
Functional relations	3.4	2.5	4.0				ED
Hypotheses relating constructs	3.7	2.0	4.0				ED
Research Development							
Reviewing the literature	3.9	2.4	4.0		SS		ED

Research Methods Topic	Importance SS	Importance MS	Importance ED	Currently Taught	
Research Development (cont'd)					
Evaluating research	3.7	2.4	4.0	SS	ED
Sources of research ideas	3.4	2.2	4.0	SS	ED
Conducting a pilot project	3.3	2.4	2.5	SS	
Research Strategies					
Correlational (ex post facto)	4.7	2.2	3.5	SS	ED
Experiments	4.0	2.8	3 5	SS	ED
Observation	3.8	2.6	3.5	SS	ED
Field studies	3 7	2.6	3.5	SS	ED
Controlled field studies	3.3	2.8	3.5		ED
Case studies	3.5	2 6	2.5	SS	
Interviews	3.5	2.6	2.5	SS	
Choosing a research study	2.8	2.6	3 0		ED
Qualitative analysis	2.5	2.6	3 0		ED
Archival & secondary data	3 0	2.2	2.5	SS	
Meta analysis	2.0	2.0	2.5		
Experimental and Quasi-Experimental Designs					
Single factor designs	3.7	2 4	3 0	SS	ED
Between- & within-subjects design	3.5	2.2	3.0	SS	ED
Static-group comparison	3 2	2 4	3.0		ED
Choosing an experimental design	3.0	2.4	3 0	SS	ED
Pre- & post-test control group	3.2	2 2	3.0		ED
One-group pre- & post-test	3.2	2 2	3.0	SS	ED
Cross-factorial designs	3.5	2 2	2.5		ED
Pre- & post-test nonequiv control	2 8	2 2	3 0		ED

Research Methods Topic	SS	MS	ED		Currently Taught		
	Importance						
Experimental and Quasi-Experimental Designs (cont'd)							
Cross-sectional, longitudinal design	2.7	2.2	3.0				ED
Interrupted time-series design	2.0	2.2	3.0				ED
Replicated interrupted time-series	1.8	2.0	2.5				
Variables and Constructs							
Independent / dependent variables	4.9	3.0	5.0	*	SS		ED
Predictors and criteria	4.4	2.2	5.0		SS		ED
Variables and constructs	4.6	2.0	4.0		SS		ED
Operational definition of constructs	3.9	2.2	3.5		SS		ED
Concomitant variables (covariates)	3.0	2.8	3.0		SS		ED
Experimental & organismic vars.	2.2	2.0	4.0				ED
Constructs - latent variables	3.0	2.2	3.0				ED
Measurement							
Types of scales	4.7	2.2	4.0		SS	MS	ED
Quantitative & qualitative measures	4.3	2.5	4.0		SS	MS	ED
Precision	4.0	2.8	3.5		SS	MS	ED
Validity and Reliability							
Internal validity	4.2	1.6	3.0		SS		ED
External validity	4.2	1.6	3.0		SS		ED
Variability, reliability and validity	3.7	2.0	2.5		SS		ED
Face validity	4.0	1.6	2.5		SS		
Criterion validity	4.0	1.6	2.5		SS		
Construct validity	4.0	1.6	2.5		SS		
Split-half reliability	3.8	1.8	2.5		SS		
Statistical conclusion validity	3.5	2.0	2.5				

Research Methods Topic	Importance SS	Importance MS	Importance ED		Currently Taught		
Validity and Reliability (cont'd)							
Alternate-forms reliability	3.8	1.6	2.5		SS		
Test-retest reliability	3.8	1.6	2.5		SS		
Control and Randomization							
Random selection	4.3	3.2	4.5	*	SS		ED
Random assignment	4.3	3.2	4.5	*	SS		ED
Eliminating alternate explanations	4.3	2.8	3.5		SS		
Sampling							
Simple random samples	4.5	4.5	4.0	*	SS	MS	ED
Probability sample	4.5	4.2	3.5	*	SS	MS	ED
Stratified random samples	3.5	2.6	4.0		SS		ED
Quota samples	3.3	2.4	3.5		SS	MS	ED
Convenience samples	3.3	2.2	3.5		SS		ED
Purposive samples	3.3	2.2	3.5		SS		ED
Cluster samples	3.2	2.2	3.5				ED
Issues in Experimental Designs							
Practical vs statistical significance	4.6	4.0	5.0	*	SS	MS	ED
Main effects	4.5	3.2	4.5	*	SS		ED
Interactions	4.5	3.2	4.5	*	SS		ED
Conducting ethical research	4.1	2.3	3.5		SS		ED
Researcher bias	4.0	2.4	3.0		SS		ED
Matching	4.0	2.4	3.0		SS		ED
Moderator variables	3.5	2.4	3.5				ED
Guarding against threats to validity	4.0	2.6	2.5		SS		
Counterbalancing	3.5	2.0	3.0		SS		ED

Research Methods Topic	Importance SS	MS	ED		Currently Taught		
Issues in Experimental Designs (cont'd)							
Attrition	2.8	2.0	3.5				ED
Carryover effects	3.5	2.0	2.5		SS		
Suppresser variables	2.5	2.4	3.0				
Blocking	2.0	2.6	3.0				ED
Change scores	2.2	1.8	3.0				ED
Interviews							
Structured & unstruct. interviews	2.3	1.8	2.5				
Fixed- & open-ended questions	2.2	1.8	2.5				
Questionnaire and Scale Development							
Evaluation of scale properties	2.8	1.8	2.0				
Types of scales	2.7	1.8	2.0				
Item construction	2.4	1.8	2.0				
Advantages of multiple instruments	2.3	1.8	2.0				
Sequence issues	2.0	2.0	2.0				
Report and Manuscript Writing							
Use of graphs and tables	4.3	4.0	3.0	*	SS	MS	ED
Discussion	3.8	4.0	3.0	*	SS	MS	ED
Method	3.8	3.8	3.0	*	SS	MS	ED
Results	3.8	3.8	3.0	*	SS	MS	ED
Introduction	3.5	3.8	3.0	*	SS	MS	ED
Use of references	3.8	3.4	3.0	*	SS		ED
Writing style (i.e., A.P.A.)	3.2	3.4	3.0		SS		ED
Defining target audience	2.0	3.8	3.0				ED

Note: Topics rated as important in all three faculties are marked with an asterisk ('*')

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Table 7.

Utilization of Teaching Techniques in Statistics Course.

Teaching Technique	% Utilizing Technique
Lecture	100 %
Discussion	99 %
In-class exams	77 %
Visual presentation	76 %
Research article critiques	72 %
Application-oriented assignments	70 %
Discussion of attitude toward research	65 %
Research project	63 %
Literature review	58 %
Small group discussion	58 %
Computer work	54 %
Small group activities	54 %
Objective exams	52 %
Term papers	52 %
Encourage students to share experiences	52 %
Cooperative learning	48 %
Small group assignments	48 %
Oral presentations	46 %
Application-oriented in-class assignments	42 %

Teaching Technique	% Utilizing Technique
Guest lecturers	37 %
Application-oriented exams	37 %
Simulation	30 %
Take-home exams	27 %
Alternative assessment (see below)	25 %
Reflective writing activity	20 %
Role playing	7 %
Games	3 %

Alternative Assessment included: Research proposal (13 %), Self-assessment (3 %), Oral exam (3 %), Poster session, Group feedback writing conferences, Dissertation proposal, Though papers on specific topics, Abstracts, Quizzes, Participation in on-going research projects, Write for publication, Observation notes and other qualitative work, Book reviews, Students can propose a creative project, Videos, Programmed units, Data analysis of data sets, and Preparation of research reports.

Source: Adapted from Lopez & Mertens (1994).