Statistical Thinking in Psychology and Education

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1. Introduction

Knowledge of statistics is important in the curricula of students in psychology and education. Reasons are twofold. First, in other courses they deal with theories and research studies which rely on statistical analysis. Second, they have to undertake research in which they have to handle, analyse and interpret data. Statistics is for these students a tool, a means of communicating knowledge which is needed to read and evaluate surveys, experiments, and other studies dealing with substantive problems in the field of psychology and education; and is also used in doing research while planning a study, analysing the data, and interpreting the results. Both aspects rely on a knowledge base of statistics and of methodology; the second also requires competence in problem-solving skills.

More specifically, we can list the statistical competences needed as follows:

(i) *Competence in reading and evaluating research:* Competence in reading encompasses: knowing and understanding the techniques used, their domain of application, and their assumptions; knowing and understanding decisions taken by the researcher concerning methodological aspects.

Competence in evaluating encompasses: competence mentioned under reading; evaluating the decisions against other competing decisions; evaluating sub-procedures used in statistical techniques; evaluating the interpretation given by the author versus alternative interpretations; competence to characterise features of the study.

(ii) *Competence in doing research:* Because of the availability of statistical computer packages, the use of complex statistical techniques is increasing. Mathematical competence is no longer the heart of the matter for using these techniques. But these packages will be of little help in planning the study, in choosing the appropriate technique, and in interpreting the results. A good statistical understanding is still needed which encompasses a certain level of mathematical sophistication and problem-solving skills.

In departments of psychology and education two conflicting research paradigms are in practice. The two paradigms are described by Husén (1988, p.17) as follows: "The positivist paradigm is modelled on the natural sciences with emphasis on empirical quantifiable observations which lend themselves to analyses by means of mathematical tools. The task of research is to establish causal relationships, to explain (Erklären). The humanistic paradigm is derived from the humanities with an emphasis on holistic and qualitative information and interpretive approaches (Verstehen)."

Scholars in the department of psychology and education have different backgrounds and rely in general on one paradigm. Although there is an agreement that both paradigms are complementary, there is an "ongoing" struggle concerning how much emphasis should be given to both appoaches.

Students also are more attracted to one paradigm than to the other. It is much harder to teach statistics to students who are in favour of the humanistic paradigm. They believe that psychology or education is dealing with unique, goal-seeking individuals for whom causal relationships are irrelevant, and where a description and an interpretation of events suffices.

2. Target group

There are three statistics courses in our department. The courses in the first and second year are compulsory for every student. The number of years of high school statistics is nil for the majority of freshmen. There is no reason to believe that their problem-solving and metacognitive skills are superior to other students leaving high school.

There is a high variation in competence in manipulating numbers and mathematical expressions, in the mathematisation of verbal expressions, and the graphical representation of functions. A mathematics multiple-choice test about basic mathematical knowledge given to 244 freshmen (Schuyten, 1978) showed (on a scale from 0 to 20) a mean of 11.35 and percentile points: $P_{10} = 6.10$; $P_{25} = 8.70$; $P_{50} = 11.55$; $P_{75} = 14.22$; and $P_{90} = 16.20$.

Analysis revealed that students had difficulties with the following:

(i) graphical representation of $|y| = x$;
(ii) work with an unknown as exponent $25^x = 0.2$;
(iii) manipulation of summation symbol Σ.

On the other hand these students showed a positive attitude towards mathematics before beginning the statistics course. They found mathematics interesting and important for their studies. They had appreciation for the processes involved in mathematical learning.

However, when you look at the students' behaviour when working statistical problems, the picture is very different. Most students after one course in statistics: (a) wait until somebody tells them how to tackle the problem; (b) prefer verbal expressions to mathematical ones; (c) memorise without trying to understand; (d) are discouraged by use of formulae.

A brief anonymous survey of psychology students after two statistics courses revealed the following: (a) 2/3 have difficulties with the course, are afraid of the quantity of formulae, and work hard on the course; (b) half of them are interested but don't agree that a psychology specialist needs a good statistical competence.

3. Specific problems

Cognitive resources: For a beginners' statistics course, most students entering university possess a sufficient symbolic competence. Nevertheless 25% show behaviour which suggests "a symbol shock". Symbols are for them an unsurmountable obstacle, which prevent them from thinking. Simple symbols such as Σ or π or indices which should help them to condense their thinking are of no help. Formulae are considered as a collection of meaningless symbols and students do not see the structure behind them. Expressions such as $Z = [\overline{X} - E(\overline{X})]/\sigma(\overline{X})$ and $Z = [P - E(P)]/\sigma(P)$ are for them two different formulae which they have to memorise. Because of the absence of meaning, they confound the symbol with the concept behind it and have difficulty in accepting that the same symbol can represent different concepts and that different symbols can refer to the same concepts (for instance, p as a proportion and a probability, $\overline{X}$ and μ for a mean).

The different levels of concreteness of a concept as used in descriptive or inferential statistics are also a problem. In descriptive statistics the unit of analysis is a person, a school, a group, and the mean of the collected data is represented by $\overline{X}$. In inferential statistics the unit of analysis is a sample and the mean of the statistic involved is represented by $E(\overline{X})$ (mean of means) or E(s) (mean of standard deviations).

The difference between the declarative knowledge of a concept and the procedural knowledge used in operationalising the concept can cause problems. Freshmen consider numbers as exact and have difficulty in accepting that you can use different procedures which could result in different numbers (for instance, median)

In a first year course a quarter of the students have difficulty in realising that a table represents a function which can be used in both ways from $x \rightarrow y$ or from $y \rightarrow x$. If you explain it with a formula $y = \phi(x)$ and $x = \phi^{-1}(y)$ you make it hard. Even after two statistics courses, 1/7 of the students have difficulties with tables.

Spatial visualisation: In the statistical decision-making process while discussing critical regions and one or two tailed testing, the making of a drawing is helpful for the majority of students. The survey mentioned in Section 2 revealed that this strategy does not work for 1/6 of the students even after two statistics courses.

Heuristics and metacognition: In choosing the appropriate sampling distribution, simple decision rules are helpful. These can be represented in a tree structure or in "if ... then ..." rules. In advanced courses the formulation of decision rules becomes too complex. Illustrations, where different techniques are used applied to the same problem, are appropriate to foster problem-solving skills and metacognition.

Group discussion about problems gives good results. This year some students worked with "Statistical Navigator" (Brent, 1989). This expert system program asks the user a series of questions, much as a human expert might, and based on the user's answers, suggests several appropriate kinds of statistical analysis ranked by suitability. In each case, it explains what the analysis does and how it does (or does not) fit the user's research objectives and assumptions. The researcher still makes the final decision, but now he or she can be confident it is an informed one. Knowledge of the program is represented through a series of "if ... then ..." rules which can be consulted.

The use of this program as a supplement to the lectures and exercises is very promising. When you observe small groups of students (2 or 3) working with the program, a lot of communication is going on between the students and between the students and the computer.

Students reflect on the logic of selecting appropriate analysis and have to elaborate and restructure their knowledge acquired during the lectures and exercises. Next year more systematic observations will be made of how students with different statistical competence work with the "Statistical Navigator".

4. Conclusions

The availability of statistical computer packages changed statistics courses both in contents and in methods used. Starting a beginner's course together with the use of a computer is attractive. Mathematical competence is not in focus and interaction is high. In my opinion there is a disadvantage that you can move very fast to complex statistical analysis without having a good understanding of the concepts involved. Another disadvantage is that it is of no help in choosing an appropriate analysis.

In advanced statistics courses it is advisable to have five parts: lectures, exercises, research problems, use of a statistical computer package, and use of an expert system program.

References

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