17. DISCUSSION: EMPIRICAL RESEARCH ON TECHNOLOGY AND TEACHING STATISTICS

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DISCUSSIONS ON "WHAT WE ARE LEARNING FROM EMPIRICAL RESEARCH"

Three issues seemed to dominate the discussions that followed the five papers presented on learning from empirical research: (1) methodological dilemmas; (2) the complexity of the development of graphicacy concepts in our students; that is, their ability to create and interpret graphs; and (3) the complexity of bivariate information in tables.

Methodology

In several cases where quantitative methodologies were used, the researchers were asked to defend their decision to adopt a methodology that quantified student thinking, and subsequently made inferences from numerical data about how students are or are not learning. "Why did you not use interviews?" they were asked. On the other hand, in several cases where a qualitative methodology was used, the researchers were asked if they thought their small sample of interviews were "normal" students, or "bad" students, or whether they felt their small sample was representative in some way of the greater picture of student thinking.

These types of questions will always accompany any research report. As researchers, we need to be up front about why we chose a particular methodology. Naturally, it should always be the case that the methodology used is driven by the type of research question asked. If at all possible, it might be advisable to use several methodologies simultaneously, particularly when we are investigating student thinking and reasoning. For example, it may be possible to supplement quantified data from student written responses or surveys with an appropriate sample of interviews with students. In that way, we might benefit from the strengths of detailed student responses, while also having access to a large sample of data. Several participants suggested that in order to obtain deep, meaningful information from interviews, we may need to probe rather aggressively, to get students to say more by asking incomplete open ended questions.

Graphicacy

Among the many issues raised with respect to graphicacy, the importance of helping students learn to transform information from graphs, and to create their own graphs to display raw data, were among the top priority. Boxplots were singled out as a type of graph that is very difficult for students to understand transform, or create themselves. The advisability of teaching boxplots to students as early as the fourth grade, a practice that occurs in some countries, was questioned. In any case, it was thought best to introduce boxplots in combination with other graphs, such as stem-and-leaf or histograms, and to display them superimposed on histograms. Both boxplots and histograms are continuous displays of datasets that were originally in a discrete format. The notion of a continuous axis is a rather complex concept, which contribute to the difficulty that students have with understanding and/or interpreting box plots. Students must first have some notion of a continuous number line to fully understand what the graphs are saying. Furthermore, once displayed, the original discrete information is lost.

Bivariate data

Several papers raised issues of the difficulties that students have when making inferences from bivariate data displayed in tables, the direction of those inferences, and the interference of beliefs about causality between variables, as opposed to association between variables, that inevitably occur. Both sociological and psychological beliefs come into play in looking at data given in 2x2 (or larger) contingency tables. The mathematics of these tables is complicated for students by their poor understanding of proportional reasoning. The improvement of student understanding of bivariate data is clearly an area that is ripe for further research, some of which has already been begun by members of this Round Table group.

WORKING GROUP SUMMARY

In the session following the presentation of papers, the conference split into various discussion groups. One of the groups was devoted to discussing the state of empirical research on the teaching and learning of probability and statistics, particularly in regard to technology. The discussion ranged over an incredibly wide area, and it is beyond the scope of this brief summary (or the capacity of this summarizer) to include everything that was mentioned. Although there was general acknowledgment that empirical research has shed light on some teaching and learning issues, it also became clear that such research often raises far more questions than it answers. In this spirit, let me summarize some of the group's discussion in terms of "where empirical research has been" and "where it might go in the future" in the area of student learning in statistics and probability.

Where we have been

A good deal of research has occurred into students' (and now teachers') conceptions and beliefs in probability and statistics. Included in this has been research into the use of heuristics (like representativeness and availability), but also a recognition of many other factors that influence people's notions of chance outcomes, such as the equally likely approach, the outcome approach, the use of casual explanations, and competing personal beliefs about statistics and chance. Many of these explanations for students' thinking about chance and data have been uncovered, or verified, through empirical research studies.

Where we may need to go

There has also been some, but not as much, empirical research into the effect of various instructional approaches (small group problem solving, teaching experiments, and teaching statistics using technological packages) on students' conceptions of data and chance. Results from this part of empirical research raise a question for anyone who is interested in research in the teaching and learning of chance and data: Are we studying "misconceptions" or are we studying "missed--conceptions"? If the latter, then methodologically, might it be better for us to think of our students' conceptions and beliefs about chance and data as "in transition" from one form to another? And so, wouldn't that change our entire approach to research, so that we would concentrate more on longer range studies of students' growth in thinking over time, rather than on documenting what students are unable to do at a particular moment in time? Long term empirical investigations of student growth were identified as an emerging research issue.

The group noted that another emerging issue in empirical research in data and chance is students' understanding of, and use of, graphs to represent data. Thus, some research into the use of technology, and how computer packages can, or cannot, enhance graphical understanding was highly recommended.

A third area noted, which was quite evident during the group's discussion, was the lack of careful attention (perhaps in teaching as well as in research) in establishing careful connections between chance and data handling. The group's feeling was that research on students' growth in learning and understanding while they work on problems that can be modeled using *repeated sampling* might provide both a pedagogical connection and a research connection between some of the big ideas of probability and statistics. A good deal of discussion and interaction took place at the conference on the use of technology to model repeated sampling problems, and to build subsequent visual representations of the data that is obtained from sampling. A number of technological packages are now available that will allow us (as teachers and as researchers) to construct settings that enable us and our students to build connections between chance and data concepts. How far could students go in establishing connections between data and chance, given the right task and a good software program?

In conclusion, the empirical discussion group suggested:

- More long term investigations of students' conceptual growth in probability and statistics.
- More research into students' graphical understanding in technologically rich environments.
- More research into the growth and development of ideas involving the connections between data and chance.