DISCUSSION: WHAT DO INSTRUCTORS OF STATISTICS NEED TO KNOW ABOUT TECHNOLOGY, AND HOW CAN THEY BEST BE TAUGHT?

1. THE VARIED FRONTIER

While the original program title, shown above, attempts to describe Thursday's session, the assortment of topics makes simple summary challenging. Four speakers from around the world spoke about a variety of topics related to technology. Rossi Hassad, from hyper-modern New York in the United States, used the Internet to survey teachers from 24 countries (Hassad, 2011) about hyper-modern Constructivist technology-assisted instruction. Anthony Bedford, James Baglin, and Michael Bulmer traveled from modern Australia to present a modern technological tool, a virtual Island (http://island.maths.uq.edu.au) designed to support student experimentation. Saras Krishnan and Noriana Idris from Malaysia, a developing country, wrote about challenges working with an older tool, the graphing calculator. In Kenya, the developing country where David Stern works, teachers still need training in word processing and the use of spreadsheets. In a different conversation, attendees from Kenya mentioned that they tried to design small class modules that can be loaded onto laptops, because frequent power outages make internet connections unreliable.

When academics in developed countries speak about technology research in education, they often imply only ideas on the frontier. Exciting opportunities like the Island exist on the technological cutting edge, and are worthy of research. Working with the Island would be difficult without electricity, however. The realities of technology vary based on position and resources. For instance, Bulmer mentioned that courses at the University of Queensland, Australia, utilize the statistical package R. The R program costs nothing, but still requires sizable investment in computers and infrastructure. Calculators have lower costs and barriers to entry. Even with substantial resources, tools can take a long time to filter through an environment. In the United States, calculator research began in the 1970s, including a government-funded "Final Report" by Suydam in 1976. In 2012, however, many U.S. mathematics and statistics classrooms still used no assistive devices, not even calculators.

Other factors affect implementation at all levels. Stern's paper discusses the complexity of technology training. During discussion, Erniel Barrios gave another complication. In the Philippines, students distracted by the newness of the techology failed to pay attention to concepts and results. New tools require acclimation periods. Stern even suggested that developing countries like Kenya have an advantage when adopting new tools, because they can avoid mistakes made by earlier implementors.

2. MATHEMATICS, DATA, AND BEAUTY

Discussion after several papers included reflection on the relationship between statistics, mathematics, and data. Participants wondered if the concept of data, numerical and non-numerical information, should become the center of statistics courses. Several participants thought otherwise. In their view, mathematics must form the foundation of the curriculum. Mathematics, particularly proof, shows how statistical processes work. Symbolism forms beauty, an appeal to the natural sense of grace.

The majority advocated against a formula-centric view. According to this position, mathematics obscures concepts and limits development. Ayse Bilgin gave an analogy, "Statistics is like prescription glasses. Mathematics is more like sunglasses and you're wearing them indoors." These people argued that aesthetically pleasing qualities arise from visualization. For instance, to develop the bell-shaped curve of the Central Limit Theorem, watching a simulation of repeated sampling has more appeal than taking the limit of a Taylor series to match a moment generating function. Letting students collect data, then discover the pattern via technological tools, creates beauty. Teachers who take a more didactic teacher-centered approach might not let students construct all the graphs, but can still provide appealing examples.

The visual concept relies on data to build graphics. Some participants wondered if data were ready to take center stage. Relatively inexpensive technologies exist to simplify conceptual visualization. Suggestions included Statcrunch and Fathom computer software, Gapminder (though limited, appealing enough to gain a 2010 BBC television special), and even the graphing calculator. Maps were also briefly mentioned. As an example, the Great Circle Mapper (Swartz, 1996) was utilized to create Figure 1, with Cebu (CEB), the nearest airport of speakers and discussants, plus a guess at the Island off the Australian coast. Is this data? Is this beautiful? Perhaps.

Figure 1. Potential data – a map with Cebu, speakers' cities, and the Island.

3. PLENARY DISCUSSION

For the final session of the day, D. S. Hooda and the author proposed six questions for plenary discussion. The questions appear below.

1. Is there a need for pedagogical redesign in view of new developments in technology?
2. At what level should statistical methods be included in the curriculum?
3. What are the effects of statistical packages on teaching and learning in statistics education?
4. How do we attract more students to research in statistics?
5. There have been hundreds of graphing calculator studies. Why isn't there a guidebook of good practice?
6. What should be the balance between realistic data and real data?

Question 1 was barely mentioned during plenary discussion, though it relates to the mathematics and data debate from the prior section of this paper. Questions 2 and 3 were not discussed at all and question 5 received only abbreviated treatment. Participants cited the problem of incentives. Guidebooks and manuals, while acknowledged as useful, do not have the same status as journal articles. Particularly at large universities, professors earn credit only for "research papers".

About half the discussion focused on question 6, the distinction between actual figures and simulated numbers. In the past, one major argument against the use of real data was convenience, since pre-compiled sources were hard to find. That situation has changed. Attendees suggested sources including nutritional content (http://ndb.nal.usda.gov), Census at School (http://www.censusatschool.com), and a CD collection of case studies from Africa. Nevertheless, other interesting topics, such as weather data in Britain, remain unavailable, so availability projects might continue to improve quality.

Participants gave reasons for working with real data, but also offered some support for realistic options. Advocates for actual figures noted that the analysis of real data has consequences, results that show applicability. Taking questions from students, and suggesting how to use statistics to generate answers, can advertise the usefulness of statistics. On the other side, realistic, manageable situations in which students can practice analysis might work better than difficult situations where complexity overwhelms learners. Simulation might prove best for learning some concepts, such as the Central Limit Theorem. While a majority of people seemed to prefer real relevant data, it was noted that little research exists to judge the effectiveness of both approaches.

The remaining debate pertained to question 4, attracting potential researchers to the field of statistics. People wondered if the question was written solely about statistics majors, or if it was intended to include a variety of students who were using statistics. The discussants meant both, since applying techniques in related fields has always been part of statistical practice. One suggestion followed from the prior discussion, exposing students to the practice of statistics. Rob Gould suggested offering "a very real problem, that's very very very hard" because challenging young minds induces motivation and creativity. Other ideas included problems similar to the book Mathematical Excursions (Aufmann, Lockwood, Nation, & Clegg, 2012) and focusing on statistics based on computing. University organizations can also contribute, by supporting BSc, MSc, and

PhD programs. Like many other problems in statistics education, improving the situation will require coordinated effort.

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