IMAGINING THE FUTURE OF STATISTICAL EDUCATION SOFTWARE

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Statisticians have long used computers to augment our abilities as humans. The graphical tools that emerged after "Software for Learning and for Doing Statistics" allowed students to visualize connections between data in ways that had previously been impossible. Now, computers can provide even more complex interfaces to data. How will the tools of the future look different than those we have today? There are new requirements for statistical education software, such as the ability to deal with large data, and the importance of reproducible research. Currently, there is a distinction between tools for learning statistics and tools for doing statistics, but we need to consider whether this gap should be closed in the future.

THE PAST

In 1997, Rolf Biehler's paper "Software for Learning and for Doing Statistics" was a call to action, arguing that the tools for statistics education could be (and should be) different than those used by professionals (Biehler, 1997). At the time when Biehler wrote the paper, almost all statistical software was intended for professionals (de Leeuw, 2009). Statistics educators, including Clifford Konold and William Finzer, had begun thinking about software for education (Biehler, 1997). But, no principled writing existed to guide the process.

As of this writing, "Software for Learning and for Doing Statistics" has been cited at least 125 times, and it can be argued that it was the spark that started an entire sub-genre of research in technology and statistics education. In particular, the development of TinkerPlots and Fathom can be tied to the paper, as they implemented many of the features Biehler outlined (Konold, 1998, Finzer, 2002, Biehler, 2003, Rubin, 2007).

At the time when they were introduced, TinkerPlots and Fathom were revolutionary. They allow users to directly interact with their data, and see interactive and reactive connections between data, plots, and other analytic products (Rubin, 2002). In 2007, Andee Rubin wrote "Much has changed; little has changed: Revisiting the role of technology in statistics education 1992-2007," outlining 15 years of technology in statistics education. Rubin's conclusion was that while technology had improved, from early tools like TableTop to the more sophisticated TinkerPlots and Fathom, many of the same struggles remained.

THE PRESENT

We are now 20 years beyond Biehler's paper. Technology writ large has changed, as has statistical software. In particular, the past 10 years have seen the development of the 'mosaic' package and the 'tidyverse' of R packages, which make the statistical programming language R easier for novices (Pruim, Kaplan, & Horton, 2017; Ross, Wickham, & Robinson, 2018). Many statistics educators have moved to use R, because it is a free and open source tool that is also used by professionals. R has been used at the high school level (McNamara, 2015, Gould, et al 2016) and extensively at the college level (Baumer, et al 2014; Horton, Baumer, & Wickham 2014). Of course, R is not a panacea for statistics education. If we take the attributes from McNamara (2018),

- Accessibility
- Easy entry for novice users
- Data as a first-order persistent object
- Support for a cycle of exploratory and confirmatory analysis
- Flexible plot creation
- Support for randomization throughout
- Interactivity at every level
- Inherent documentation
- Simple support for narrative, publishing and reproducibility
- Flexibility to build extensions

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R still struggles to offer easy entry for novices, and students can get bogged down in syntactic details.

On the interactive side, TinkerPlots and Fathom continue to be used in educational contexts (Biehler, Frischemeier, & Podworny, 2017; Konold, Finzer, & Kreetong, 2017). Compared with R, these tools continue to have a lower barrier to entry, and make it easier to see connections between aspects of data analysis. However, TinkerPlots and Fathom are starting to show their age. Their interfaces, which were so revolutionary in the early 2000s are now beginning to feel outdated.

THE FUTURE

Like Biehler in 1997 and Rubin in 2007, we are once again in a place to consider where we have come from and where we are going with statistical education software. Again, the attributes from McNamara (2018) can serve as a guide. There are no currently-existing software packages that fulfill all the attributes outlined. Imagining a tool that fulfills all the attributes is an exercise in considering how aspects of programming languages like R could be combined with the interactive power of tools like TinkerPlots and Fathom. We seem poised for another leap forward, much like the one we saw in the early 2000s. Our statistics education tools can do more than amplify our abilities, but also augment them (Pea, 1985).

Perhaps a domain-specific blocks-based language could be created, blending the best of an interactive tool with the reproducibility of a programming language. In computer science, the GP project aims to bring this sort of layered approach to Scratch, a popular blocks-based language for teaching (Maloney, Mönig, & Oshima, 2015). Another idea would be to tighten the feedback loop between editing code and seeing results, as proposed by Bret Victor in his essay “Inventing on Principle” (Victor, 2012). Or, perhaps humans’ interactions with computers will come out of the box, and we will program by manipulating physical objects in our environment, as Victor’s current research group is exploring (Victor et al, 2018).

Throughout all these explorations, we need to keep in mind how people envision data and data analysis in their mind’s eye. What are the most natural representations of data? We can consider research on how learners have previously conceived of data (Konold, Finzer, & Kreetong, 2017), as well as principles for data management (Wickham, 2014). Many aspects of statistics are counter-intuitive, and as scientists we do not want to bias our results. How can computers support humans in their statistical work? Elements of randomization may support this, as well as graphical inference methods (Wickham, Cook, Hofmann, & Buja, 2010).

Can one tool support a person through the entire life cycle of learning to doing? For years, people like Rolf Biehler and James Baglin have argued for the importance of distinct tools for learning and doing statistics (Biehler, 1997, Baglin, 2013). The gap may be closing, and technology could serve to bridge what is left of the gulf (McNamara, 2015). But should it?

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