Forward teaching: Recommendations for improving statistical literacy in psychological and behavioral sciences

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Abstract

To improve outcomes in statistics education - namely the acquisition of statistical literacy - we need a new approach to how the subject is delivered in psychology and behavioral sciences. To do this, key indicators and impacts of barriers to learning statistics can be utilized from existing evidence from recent findings on statistical literacy. Using these, this paper proposes nine elements seen as critical for improving the delivery and associated outcomes for statistics teaching in higher education. Each of the nine elements may be systematically assessed and translated for wider use if effective.
Introduction

Students do not like the way statistics are taught. This may not come as a surprise to many, but the consequences of this negative experience are significant for students (Chiesi & Primi, 2010) as well as for professors (Uttl & Smibert, 2017) and populations (Calzada Prado & Marzal, 2013). These implications have been highlighted in a recent paper in this journal, which indicates that teaching in quantitative subjects is a strong predictor of lower student evaluations when compared to other topics Uttl & Smibert, 2017). These findings were tied to negative outcomes for academic career progression, which likely has unstudied consequences on the experience level of those responsible for teaching the course.

Those who attempt statistical teaching interventions should be commended for recognizing that traditional approaches to teaching statistics may not be as effective or as desirable. The perpetuity of similar findings implies that not everyone acknowledges an issue even exists, though this may also be linked to high turnover in who teaches. While some academics attempt various efforts and even build interventions through a solid theoretical base, this approach has been generally limited. While some techniques may appear obvious, even the cursory scanning of teaching guidance for statistics will reveal much advice has little evidence base and resorts to anecdotes (e.g. ‘In my experience…’), blogs, or untested pieces whose review is limited to the idea rather than empirical evidence – an odd result considering the sources.

There is a growing body of evidence for understanding what hinders acquisition of statistical thinking. As those become better identified, academics should be encouraged to attempt scientifically validated improvements to how we engage our classrooms (Kottemann & Salimian, 2008), especially when it comes to deep understanding of statistics anxiety (Chew & Dillon, 2014). That educators are now working in earnest to contribute to this presents a positive outlook for a potential future of long-awaited statistically literate populations (Wallman, 1993). Anecdotes, however, have yet to produce a sustained improvement. We need more than this.

Take the example of classroom activities used early in the teaching of statistics as a way to improve outcomes (Chiou et al., 2014). This method employs a previously validated one-minute exercise (Stead, 2005) meant to engage students in such a way that statistics anxiety should be reduced and lead to improved test scores. The result: grades increase marginally, a contribution is added to the ‘bag of tricks’ (Gelman & Nolan, 2002), and another anecdote goes into circulation. Without seeking to discredit interventions that show some benefit, the following piece is an argument – even a plea – that if we are truly devoted to gainful change from teaching statistics, it will require more than a minute, clever lecture anecdotes, or new approaches to assessment.

We require a new way of thinking about how to deliver the skills, techniques, and mindset necessary for populations that can think statistically. Such abilities enable more people to make better decisions based on information provided, whether in scientific study, government policy, or everyday living (Chew & Dillon, 2014). Unfortunately, the same studies that generate these insights indicate that statistics anxiety is a major barrier to realizing them, largely due to statistics anxiety (Chew & Dillon, 2014). The necessary, substantial change to overcome this begins with the person at the front of the lecture hall. However, this requires implementing evidence-backed approaches to teaching, not simply more assessment of interventions and the students enrolled in them.
To respond to this, we propose a way of moving forward with our teaching (or ‘teaching forward’). To do so, this piece offers a brief review of relevant barriers to acquiring statistical literacy, namely statistics anxiety, followed by a set of evidence-based proposals for how to reduce those challenges through better teaching. Though some elements will seem common sense, evidence indicates there are many instances where they are not in place, and it is hoped that this will at least spur meaningful debate toward that end.

What we already know

Statistics anxiety, its precursors, and its impacts, are well understood. This has largely been through work using the Statistics Anxiety Rating Scale (STARS; Cruise, Cash, & Bolton, 1980). STARS has been the prevailing measure for study, and recent validation work confirms most of its properties continue to hold (DeVaney, 2016). Statistics anxiety is not limited to the social sciences or to English-speaking regions, which has been confirmed by recent work in medical students (Stanisavljevic et al., 2014; Gaudet, et al. 2014) as well as on several continents (Papousek et al. 2012; Liu et al., 2011). To briefly summarize:

1. Students in the behavioral, social, and biological sciences are pretty anxious about statistics as a class, assignment, and examination (Field, 2014; Baloglu & Zelhart, 2004).
2. Some anxiety is not a bad thing; a lot of anxiety is (Macher et al., 2015).
3. Performance in statistics is a subjective measure – we can do better as educators at assessing this (Macher et al., 2013) but should be careful about teaching to the test.
4. Teaching is the ultimate moderator: do it right and you are much more likely to get a positive result with a larger number of students; do it wrong and you lose people (Ruggeri et al., 2008). The latter is much easier and more common.
5. The people who teach statistics are not always in love with the subject, either (Martins et al., 2012).
6. Introducing innovative activities, materials, and teaching styles in the classroom may lead to improved outcomes, but many proposed approaches have not been rigorously evaluated or followed up (Chiou et al., 2014; Gould, 2010; Field, 2009).
7. Statistics anxiety is not merely a classroom and performance issue, but one that may impact student well-being, particularly of more vulnerable groups (Jordan, et al., 2014).

What can we take from the evidence so far?

No first-day activity, no single joke, no vivid anecdote is likely to address all issues faced in ensuring statistical literacy is gained by the greatest number of students. This holds true even if lecturers are able to deliver them. Why is this a problem? If the people who are trained specifically to be analytical (i.e. scientists) struggle to grasp statistical inference, then it is unlikely the general population can easily understand quantitative information presented from any number of sources (Ruggeri et al., 2011). Such arguments are backed up by any number of examples from mainstream media and scientific papers about misunderstanding topics such as risk (e.g. Spiegelhalter, 2013).

Instead of a simple response, we need to rethink our approach to how the subject is taught from the outset. One-off activities may offer some impact, but even so, the potential gain from going further than this cannot be missed based on small increases in exam scores. The same may be said of using humor (Field, 2009), guest speakers from professions of interest to students (Ruggeri,
2009\(^1\) and other ‘tricks’ (Gelman & Nolan, 2002). It is unsurprising that these may offer little impact when not utilized within a wider strategy but instead simply called upon for the occasional change of pace.

The evidence ultimately indicates that we need systematically assessed approaches to teaching that demonstrably and reliably reduce the legitimate impacts created by mathematical and statistical anxiety. These barriers currently result in low retention of students and knowledge acquisition as well as the avoidance of quantitative information in some more severe cases (Alexander & Onwuegbuzie, 2007). Any new approach should extend beyond simply new forms of presenting the same information for improved test performance, but instead to aim for advances in statistical thinking relevant to modern influences and demands (Cumming, 2014; Gould, 2010).

What we need now (the opinion part)

In the classroom, there are myriad options for approaching essentially any topic taught in statistics. As such, one could reasonably argue it may be equal parts art and science. This is complicated further given the unlikelihood of engaging all students equally with one style or activity. However, amongst the worst approaches is to present merely theoretical or formulaic knowledge without a deliberate effort to provide context, examples or other applications. Furthermore, superficial approaches to context whereby a passive reference is presented following a complex description of a skill will do little to enhance understanding.

Telling a joke or a story at the beginning of the lecture will simply not be enough to make students learn. The effort to reach more students comes long before the classroom, in committed preparation beyond pulling pages from a textbook but rather stories from experience or significant exposure (Chew & Dillon, 2014). In this way, the approach to developing teaching materials is very much a science (Wainer, 2011) and should be evaluated as such.

Without question, developing this requires tangible support from the institution as many lecturers are simply too overwhelmed with other obligations to devote time to improved teaching. This is further problematic when balancing between advancing personal statistical skills and teaching material that is only new for students. Beyond that, while there is good evidence in support of humorous approaches, a mixture of styles may be more useful. For example, utilizing entertaining topics prior to referring to serious matters of statistical relevance such as the Challenger crash or social debates about airport screening and human approaches to error. This is certainly not an exhaustive list; the key is to leave an impression through keeping minds engaged (Kottemann & Salimian, 2008; Wainer, 2005), and empirical support for broadly effective approaches is no doubt lacking. Given the low availability, simply continuing to study statistics anxiety further or promote anecdotal teaching improvements risks redundant confirmation of issues matched with negligible improvements in grades.

If not abundantly clear from the general tone of this writing, this in no way implies that statistics is somehow unique from other university-level courses. Nobel laureate Ronald Coase long argued, for example, that economics is simply not taught in such a way to ‘enlighten the public’ on the use of resources, but instead is approached on what academic economists need to know to publish papers in academia. Much of the same could be said about statistics and a wide body of literature

\(^{1}\) Author highlights this is not a peer-reviewed reference. Findings from this study showed no significant difference and thus received no interest from journals.
suggests similar thinking in many other fields as well. When we know more about ‘economics anxiety’, expect another paper.

To address these challenges, nine approaches are proposed to implement into teaching. Where utilized, they should be studied for effectiveness in the acquisition of statistical literacy beyond grades. While some may have the appearance of common sense, a recent review confirms that many are simply not applied in practice (Chew & Dillon, 2014).

1. Focus on inspiring students (who will form part of the general population) through the benefits of statistical understanding and application far ahead of the necessary calculations. If they understand the language, meaning, and importance, they are better prepared to apply it.

2. Constantly emphasize applications through examples. If you are teaching it in a university, you should have used it in practice.

3. Balance the emphasis on formulae and decision-making at least until understanding of the context is evident. Anyone can refer to a textbook for guidance on how-to; knowing when and appreciating why are much more relevant battles in the classroom.

4. Do not start out by teaching statistics within the context of a calculator or software packages. Teach the fundamentals and reduce anxiety through demonstrating the value of statistical knowledge. In other words, get rid of the black boxes.

5. Be engaging. There are more approaches than just adding humor that can captivate a classroom with the importance of statistical thinking – students will respond to the most sincere, whether it is with laughter, tears or personal experience.

6. Never let students lose sight of the principle that statistics is a tool to be used in answering questions – research or otherwise – not vice-versa. We do not conduct research to use statistics; we use statistics when necessary to answer questions when we have appropriate data. The statistics are not the boss, but rather they are the tool.

7. Even if well-intentioned, do not simply develop a plan to assist those struggling to learn. Implementing the previous six points would build toward a forward shift in classroom (i.e. population) outcomes, offering gains for all students.

8. Focus on critical thinking instead of covering more chapters. Teach ‘The New Statistics’ (Cumming, 2014) before jumping to Bayesian cognitive modeling (Lee & Wagenmakers, 2014), no matter how much the latter will be more likely to draw a keynote invitation. Such topics should come when students have a firm grasp of the fundamentals relevant to the skill as well as considerable practice. Remember: just because we don’t teach it doesn’t mean they won’t learn it.

9. Do not focus merely on teaching how to generate results. Teach how to identify patterns, infer from partial information, interpret ethically, and to illuminate insights.

Collectively the idea is simple: if the mindset and fluent statistical thinking are delivered, students can go much further on their own than if topics, theory, and calculations are simply thrown at them (Gould, 2010). These points are meant as means to engage all students, not only to cover required

2 Statistics lecturers may want to have someone check those stories before using in class. What we find interesting is not always what students find interesting.
topics or attempt to help those struggling. Together, they would provide the ability to understand, to be critical, and perhaps most sustaining, for students to be able to go much further on their own, far beyond their time in the classroom.

Delivering this level of statistical literacy would be nothing short of empowering, and current trends in data usage will offer new ways to assess if this has been addressed. For example, could students independently explain why data privacy matters? Could they generate data from scratch to show how online behaviors can be used to derive a large amount of information about individuals? Even without teaching these specific skills, such thinking is a better indication of literacy than simply being able to recite formulae or produce an essay on Item Response Theory algorithms.

Ultimately, the purpose of teaching is to inspire: an inspired mind will go far further with knowledge than simply recalling what is presented in a class. No evidence has been presented to have challenged this conclusion and the present argument suggests that such an approach is possible and measurable. It is now time for us as educators to put to practice – both the teaching and the analysis. Should anyone disagree, please note all nine points above are testable hypotheses. Please hold your rejection until appropriate tests have been carried out.

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