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INTERVIEWS WITH STATISTICS EDUCATORS

Interview With Larry Lesser

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Photo courtesy of Lauren Davis.

Larry Lesser is a Professor in the Department of Mathematical Sciences at The University of Texas at El Paso. He is also a UTEP Distinguished Teaching Professor whose awards include a 2016 Minnie Stevens Piper Professor Award, the 2012 International Sun Conference Scholarship of Teaching and Learning Award, a 2011 UT System Regents' Outstanding Teaching Award, and the MAA Southwestern Section's 2010 Distinguished Teaching Award.This interview took place via email from January 17–February 16, 2020.

Beginnings

AR: Thanks very much, Larry, for agreeing to be interviewed for the Journal of Statistics Education. *How did you come to be a statistics teacher and statistics education researcher?*

LL: My pleasure, Allan—I'm a big fan of this series, so this is exciting—and humbling. I took my first statistics class after a year in the mathematics PhD program at The University of Texas at Austin. That course from Peter W. M. John inspired me to change programs to statistics, getting an MS degree and starting in fall 1988 to teach college introductory statistics courses. Next, I took the first actuary exams, worked half-time for a couple of years as the staff statistician for a state agency [Texas Legislative Council], and completed all coursework for a PhD in statistics. Largely due to the part-time teaching I was doing (for UT-Austin, St. Edward's University, and Southwestern University), I came to see that studying the teaching and learning of statistics was an even greater interest, calling, and strength for me than statistics itself, so I enrolled in UT's mathematics education PhD program.

The world had no statistics education PhD program then, but I was fortunate to have a committee at UT that supported my atypical pursuit of a statistics education dissertation and tailored my program accordingly. My committee had math educators (Ralph Cain [chair], Ray Carry, Charles Lamb) and statisticians (Maggie Myers, Mary Parker). And in those pre-*JSE*, pre-*SERJ* days, it was a godsend to also have support from key people not on my committee, especially Joan Garfield who promptly mailed me a bountiful packet of articles to orient and welcome me to the field. My review of an article by Burrill (1990) fulfilled an assignment in Cain's EDC 382S course, evolved into a research paper in Carry's EDC 385G course, and then grew into my dissertation on counterintuitive examples in statistics education. That topic was a fun place to start because it felt like a genuinely open question about whether a counterintuitive result would more likely intrigue or demoralize a student.

AR: I have to ask: What did you learn about the use of counterintuitive examples: Are they more likely to intrigue or demoralize a student?

LL: The strategy isn't foolproof, but evidence suggests thoughtfully and interactively introduced counterintuitive examples more likely intrigue (see Appendix C of Lesser and Kephart 2011).

AR: I'm glad to hear that, because I like to use examples of that kind. But I also try not to overdo it with counterintuitive examples, and I make a point to use many examples that confirm students' intuition and predictions. Do you agree with that approach, and do you know of any research results along those lines?

LL: Yes, less is more! A counterintuitive example—or, for that matter, a social justice example, song, or magic trick—has more impact if used only occasionally. So, yes, most of the time I use lessons (e.g., Lesser and Melgoza 2007) or analogies (Lesser 2016b) that build or confirm intuition. For at least three decades, science education has studied a "bridging analogies" or "anchoring concepts" approach, but I'm not aware offhand of a study comparing that head-to-head against a counterintuitive examples approach. In any case, I found that these approaches can work together: a counterintuitive example can be the hook to launch a lesson, and after students wrestle with it, an intuition-building analogy can help resolve it (Lesser 2006).

AR: Can you describe one of your favorite counterintuitive examples?

LL: I love Simpson's paradox because reversal of a comparison upon aggregation happens in real life, is essential for citizenship (National Council on Education and the Disciplines 2001), and even a middle schooler can do fraction arithmetic on a table of numbers to verify that it *is* possible and yet most adults haven't seen a representation that illuminates *how* it is possible. NCTM

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kindly let Milo Schield post on his impressive statistical literacy website a paper (Lesser 2001) with many representations of the same data set to make that initially counterintuitive result seem intuitive in hindsight. (Speaking of Milo, I'll always be grateful for how he reached out and encouraged me two decades ago, before my career was really clicking, and I've so enjoyed our interchanges on statistical literacy topics over the years.)

AR: Did you begin your career at UTEP immediately after finishing your dissertation? What attracted you to UTEP?

LL: UTEP actually was one of my four offers as I was wrapping up my dissertation in 1994, but I would have been the department's only math education professor then and I felt my career would be better launched in a team of math ed colleagues. To balance family and professional objectives, I spent the next decade getting varied experience at University of Northern Colorado, Armstrong Atlantic State University (now Georgia Southern University Armstrong Campus), and an innovative Houston high school (whose math department I chaired for its second and third years).

When UTEP had an opening in 2004, it was the right time to go there as there was then a critical mass of colleagues and support to focus more on research—in particular, on statistics education research. I was attracted by UTEP's commitment to access and excellence for its students and by its ambition to raise its research profile and, indeed, last year UTEP reached Carnegie R1 status. Also, I loved the region's low cost of living, low crime rate, beautiful mountains and desert, cultural richness by the borders of Mexico and New Mexico, and warmth of its people (including some cousins). I guess my intuition was good because this is where I've had my career's best productivity and collaborations, including a strand of statistics education research on English language learners that was simply not on my radar before I moved to this borderland region where roughly 80% of the college students (and residents) are Hispanic/Latinx and 5% of UTEP students commute across the bridge from México.

Preparing Future Teachers

AR: What classes do you teach most often, and what are the student audiences in those classes?

LL: A typical year includes one or two courses (e.g., introduction to the field, quantitative research methods, qualitative research methods) in our Master of Arts in Teaching Mathematics program as well as some undergraduate courses, especially teaching and coordinating the statistical literacy course using the wonderful book by Utts (2015). I've taught that course here two dozen times and still love it! Most courses I teach have an audience that's largely or completely pre-service or in-service teachers, so I'm glad I took the time to get that precollege teaching experience before coming to UTEP. By being geographically isolated from major cities, El Paso is a closed loop where UTEP graduates tend to come from and stay in the region, so it's powerful to know our impact gets amplified in local schools.

AR: What are some lessons from your precollege teaching that you impress upon your students?

LL: I've found authenticity and credibility in sharing not just "here's what I read in a research article" but also "here's what happened when I taught this topic to my [Algebra I, Geometry, Algebra II, Precalculus, or Calculus] students." A big pedagogical takeaway from those years relates to motivation. Many high schoolers aren't in math class by choice—some might not even be in *school* by choice!—so I had to brainstorm more ways to make material engaging. Some ways included educational songs or making beyond-the-textbook connections to their other subjects, culture, or current events, and I enjoy doing that with my college classes, too.

Another takeaway relates to assessment. A traditional college lecturer not using active learning might not know things aren't clicking until seeing results of that first midterm—yikes! Instead of lecturing the whole period, however, a high school teacher typically discusses questions about the previous homework, concisely teaches some new material, and then lets students practice the new concepts or start new homework and get some feedback before class ends. To build in more informal assessment for my high school classroom, I obtained a class set of personal-sized dry erase markerboards so I could pose questions for *all* to answer, not just the same volunteers. So it felt natural to try something in that spirit when I resumed university teaching. The tool I liked best was ABCD voting cards (Lesser 2011), and I also started varying my instructional modality more over the 80 minutes of a typical college class period. I really feel my high school teaching made me a better college instructor and led to my teaching awards.

AR: Please tell us more about the Master of Arts in Teaching Mathematics program. What are the backgrounds of typical students, and what are typical career paths and goals for those students? What coursework or other curricular experiences does the program entail?

LL: Typical students are local high school teachers who teach a full day and then drive across town to UTEP two or more days a week for evening classes, so it's real commitment. These teachers are wonderfully dedicated people, and I learn a lot from them about dynamics of today's high school setting. Half of the program's coursework involves classes to further their mathematics knowledge (and connect it to the mathematics they teach) and the other half involves math education classes that equip them to navigate the literature and conduct practical research in their own classes. The upshot of the program is that they become more thoughtful teachers in their classroom and also become eligible to teach introductory courses at the college level if they want to pursue that. Additionally satisfying for me are the times when a student elects to do a statistics education thesis or coauthor a paper. But perhaps the best answer to your question comes from students' own words in our recent promo video: *https://www.youtube.com/watch?v=RL49JTTu_Ok&feature=youtu.be*.

AR: You mention courses that further the teachers' mathematics knowledge. Does that include enhancing their knowledge of statistics? Are any statistics courses offered in this program?

LL: The large majority of the teachers take our course on quantitative research methods, which enhances their knowledge of statistics as it prepares them to interpret statistical data on their students and do some of their own data collection and analysis.

AR: Do you know whether many of these teachers teach statistics themselves? Do you have any sense of their attitudes toward statistics? For example, do you think they feel comfortable or enjoy teaching statistics?

LL: Though we haven't formally collected data on their attitudes toward statistics, I'd hope that their attitude and self-efficacy to teach statistics improve from what they get from our course. Most teachers have their high school schedule filled with only non-statistics classes, though some of those courses include a statistics topic like line of fit. And teachers also have a chance outside their teaching to apply their newest statistics knowledge when, for example, they have departmental meetings to analyze results from the latest benchmark or high-stakes testing.

Songs and Fun as Teaching Strategies

AR: Earlier you mentioned educational songs as a teaching tool. You are well known for composing and performing such songs. How did this originate?

LL: Though it's no more than 1% of class time, it may be the most memorable thing I do per minute and, especially for our non-majors, it really helps humanize STEM, STEM class, and STEM instructors. So how did it start? I became a math major and began writing songs about the same time, after my freshman year at Rice. In college, my songwriting was more of a raw vehicle for personal growth than crafted art for the world, but during my grad school years, my songwriting came of age in Austin's wonderful songwriter community where I served as Austin Songwriters Group VP and released an original singer-songwriter cassette-only album. So for a decade, my songwriting and STEM paths were separate, but as I began teaching, I sought creative ways to engage students.

While teaching precalculus at Southwestern University in 1992, I created a project in which student teams explored mathematical connections in the structure of music. While teaching calculus at the University of Northern Colorado in 1994, I wrote (and performed in class) my first STEM song—"Take it to the Limit," to the tune of the same-titled Eagles hit, so it was truly a derivative work. Sorry, I'm also well known for my puns!

The surprisingly strong positive response to those initial efforts encouraged me to do more, but I had absolutely no clue that the subsequent quarter-century could yield song-related studies, grants, journal articles, contest awards, conference performances, radio/TV appearances, some 100 published educational songs, and an international network of kindred spirits (*https://www.CAUSEweb.org/voices/*)!

I'm so grateful I managed to integrate my passions in a way that's valued by my students, institution, and field (*https://larrylesser.com/mathemusician/*). And even my latest non-STEM songwriting has educational leanings: I fulfilled a bucket list item by professionally recording this past summer an album of original songs grounded in Jewish text with universal lessons (*https://larrylesser.com/sparks/*) and releasing it in February at events sponsored by UTEP Religious Studies.

AR: I encourage JSE *readers to follow these links to see and hear some of your songs and other creative compositions. May I ask you to describe a sample of just three of your favorites that you would recommend for statistics teachers to look at first?*

LL: I'll start by choosing "What P-Value Means" (*https://www.CAUSEweb.org/cause/resources/fun/songs/what-p-value-means*) because what else can we do in 10 seconds to help students internalize such an important nuanced definition? I love how well USCOTS 2013 banquet attendees sang this as a round! Now since not everyone realizes how songs can go beyond short mnemonic jingles to also be vehicles for discussing concepts, my second nominee is "Losing Cause," which illustrates how correlation need not imply causation. This song has teaching tips in Lesser (2018b) and a recording at *https://www.CAUSEweb.org/cause/resources/fun/songs/losing-cause*. I'll complete the trio with what may be my "greatest Lesser hit"—my lottery education outreach song "The Gambler," which has been played at the NCTM conference, USCOTS, MathFest, a Denver radio station, and MoMath. A video from the latter (*https://www.CAUSEweb.org/cause/resources/fun/videos/gambler*) shows how I like to incorporate humor and visuals.

AR: In addition to songs, what are some of your other teaching strategies or activities that you would classify under the label of "fun"?

LL: Let's see—I use a couple of magic tricks (Lesser and Glickman 2009) when I teach probability. I also write statistics poems (e.g., Lesser 2020) and love when some students take me up on an extra-credit opportunity to make their own statistics poem, song, or video (Lesser 2018a). I also grab other types of items from the CAUSEweb.org fun collection such as cartoons or the game of guessing correlations from scatterplots. And there are other activities I can't resist, like having students get out of their seats and form a human scatterplot (O'Keefe 1997) or play Skunk (Brutlag 1994). I also enjoy having the class play "Deal or No Deal" in class and then debrief a clip [from Season 4, Episode 7, that NBC aired October 22, 2008] where a contestant down to two cases—$1 million or $1—says "no deal" to the banker's less-than-expected-value offer of $416,000 and ends up with $1. I've also created statistics mini-lessons to accompany syndicated comic strips (e.g., see the spring 2018 *Teaching Statistics* and the October 2016, February 2015, September 2012, March 2010, April 2009, and May 2008 issues of *Mathematics Teacher*). Last fall, Dennis Pearl and I launched a *Teaching Statistics* column that tries to integrate varied fun modalities and activities for specific learning objectives for a given topic, but *JSE* readers wanting a quick broad tour of educational fun in statistics might start with my *Amstat News* piece (Lesser 2017a).

Statistics Education Research

AR: Am I right that you and colleagues have conducted research into the effect of fun activities on student learning in statistics? Can you summarize the primary findings of this research?

LL: Yes, we're serious about fun! Shortly after CAUSE Director Dennis Pearl launched CAUSEweb.org, we started co-curating its Fun Resources collection and wrote a review paper (Lesser and Pearl 2008). At USCOTS 2009 and 2011, we convened an NSF-supported CAUSE Study of Fun cluster with disciplinary, institutional, and geographic diversity. That cluster produced a paper (Lesser et al. 2013) surveying statistics instructors on their motivations and hesitations for using educational fun. Dennis and I then partnered with John Weber from Perimeter College at Georgia State University to land an NSF grant (Project UPLIFT) to do randomized experiments on the effect on learning and anxiety of fun items (e.g., songs and cartoons). One striking finding was that students who had been randomized to receive in their learning management system a song insert in their (otherwise self-contained) readings on specific learning objectives correctly answered corresponding test items an average of 7.7% more often than other students (Lesser, Pearl, and Weber 2016).

Reflecting on that experiment led to our current NSF grant (Project SMILES) to write and assess songs that are "interactive"—kind of like the Mad Libs^{TM} word game—where students give inputs in advance that end up highlighted in the completed song on the playback page. We detailed our process in the last *JSE* (Lesser et al. 2019), and a 3-min overview video is on our project website: *https://www.CAUSEweb.org/smiles/*. Pilot studies at a research university and at a majority Black two-year college showed students found the innovation to help their learning and lower their anxiety. (Our main goal is the learning, whether that happens because they learn directly from the fun items or because the fun items lower anxiety so that more learning is possible.) Analysis of log files from the use of the software shows some evidence of better performance on assessments after use and informs ongoing improvements of the automated feedback. We think those log files have a wealth of information that will help us better understand how students think as they interact with the pre-song prompts.

AR: You mentioned earlier that you also use social justice examples in your classes. Would you describe a favorite example or two?

LL: I enjoyed extending the literature on teaching mathematics for social justice to the realm of teaching statistics (Lesser 2007), but am even happier to see how many others have written on the topic since then. The latest social justice example I used in my classroom was an exploration of statistics involved in measuring lead levels in household water in Flint, Michigan (Loux and Gibson 2019). I hope it goes without saying that all people should have access to safe drinking water and my students seemed particularly reflective and engaged by the context of this recent highly publicized public health crisis.

AR: You also mentioned that your move to UTEP prompted some research in the learning of statistics by students for whom English is not their first language. What are your primary findings from this research?

LL: More than the sum of the papers (e.g., Lesser and Winsor 2009; Lesser et al. 2013; Lesser, Wagler, and Salazar 2016; Wagler and Lesser 2018; Monárrez et al. 2018; Lesser in press), this strand has been a journey—the way the topic emerged organically from my environment, the way it supports UTEP's commitment to access for the population it serves, the way it parallels my personal life (Lesser 2015), and the way it's tangibly changed my teaching and writing to be more accessible for *all* students, not just the emergent bilingual learners. I was fortunate to team with local colleagues who knew more linguistics, Spanish, or statistics than me, especially Amy Wagler, Matthew Winsor (now at Illinois State), and Alberto Esquinca (now at San Diego State), and we also collaborated and coauthored with many graduate students and an undergraduate.

We learned much about the dynamic of navigating among registers of language, distinguishing between mathematical, statistical, and everyday uses of a word and this aligns with the fine work of Jennifer Kaplan's lexical ambiguity research team whose first paper (Kaplan, Fisher, and Rogness 2009) actually appeared the same month as ours, and we found further overlap when we all were part of the invited session on language you chaired at JSM 2012. With English learners, there's the additional complexity that these registers exist in both English and in Spanish, and an English learner will typically understand everyday English several years before they are able to comfortably handle the kind of English academic discourse that happens in college classrooms.

Here's a concrete example of something we learned: a phrase like *in the long run* seems simple because each of its words is one of the 1000 most common English words, but knowing individual words does not ensure understanding an intact phrase. (A teaching tip from Amy Wagler is to signal to students that this is an intact phrase by putting quote marks around it when introducing it.) However, the Spanish phrase *en el largo plazo* translates to the less idiomatic *in the long term*. Another example of how Spanish is a resource is that the word *confounded* is not nearly as common in English as its cognate *confundido* is in Spanish. Because of this, a Spanish speaker may be more likely than a native English speaker to infer or recall that confounded variables have effects that are "confused" or all mixed up.

Our surveys and case study interviews also yielded instances of how context may need to be unpacked for someone new to English or the nation's culture. The good news is that there are pedagogical practices and resources that can be readily implemented (a concise list is in Table 2 of Wagler and Lesser 2011). Our English learner work also spawned papers on other language-related topics, including readability (Wagler et al. 2015; Lesser and Wagler 2016) and mnemonics (Mocko et al. 2017), and I've also written on other diversity-related topics (e.g., Lesser 2010, 2014).

AR: Thanks especially for the two concrete examples that help me to understand this issue better. Can you also give a concrete example of how you have changed your teaching to be more accessible to all students?

LL: Sure. The technique of sentence frames seems to help everyone. For example, if I just ask the class "What is the definition of a z-score for an observed value in a data set?," it's sometimes silent even though I know many students know the answer, but when I then offer a scaffolded sentence ("It's the number of ____ above the ____."), students readily complete the sen-

tence correctly. And in my written assessments and curriculum materials, I learned to aim for more streamlined wording—fewer clauses, less passive voice, shorter noun phrases, shorter sentences, simpler words. To illustrate, here's a procedure I wrote (COMAP 2009, p. 161) for finding the first quartile: "Use the median to split the ordered data set into two halves—an upper half and a lower half. The first quartile is the median of the lower half." Surveyed students (whether English learners or native speakers) strongly preferred that wording to that textbook's prior edition: "Arrange the observations in increasing order and locate the median M in the ordered list of observations. The first quartile is the median of the observations whose position in the ordered list is to the left of the location of the overall median."

AR: What other topics of research in statistics education might you like to mention?

LL: We've covered much ground with counterintuitive examples, social justice, educational fun, and language—which I view as all falling under the umbrella of making statistics more accessible, meaningful, and engaging. Or maybe I'm a tad scattered with finding so many topics fascinating—I'll let the reader decide! A favorite paper of mine that doesn't fall into those four areas presents and assesses the effectiveness of a balance model for the median (Lesser, Wagler, and Abormegah 2014). The median sounds so simple, but many students lack full conceptual understanding and not many instructors seem to know about its low-tech robust physical model.

I also have to mention a research team in which I've played a lesser role (no pun intended this time) for over a dozen years. At USCOTS 2007, as a member of the CAUSE Research Advisory Board, I was designated as a mentor for a CAUSEmos research cluster that focused on K-12 teacher preparation to teach statistics, work informed by the Pre-K-12 GAISE (Franklin et al. 2007) and, later, the CCSSM (National Governors Association Center for Best Practices and Council of Chief State School Officers 2010). Our team applied Rasch measurement theory and Bandura's social cognitive theory to develop the Self-Efficacy to Teach Statistics instruments, the first instruments measuring pre-service teacher efficacy for teaching middle grades (SETS-MS) and high school (SETS-HS) statistics. The team gathered and documented validity evidence for the scores from the instruments (Harrell-Williams et al. 2014a; Harrell-Williams, Lovett, Lee, et al. 2019; Harrell-Williams, Lovett, Lesser, et al. 2019), explored the statistical topics that pre-service teachers feel most and least confident about teaching (Harrell-Williams et al. 2014b), and made progress toward identifying factors involved in pre-service teachers' ratings of these topics. The team's driving energy has always been Leigh Harrell-Williams of the University of Memphis, and other members are Alejandra Sorto (Texas State University), Rebecca Pierce (Ball State University), and TJ Murphy (University of Cincinnati). I don't have a big background in psychometrics like Leigh, so I learn a lot with this team. Its members are incredibly supportive and collegial, which is a big reason I've remained with them well past my initial mentoring commitment. Our only disagreements are when two individuals each insist that their own name should be listed *lower* in a paper's author order!

Statistics, Mathematics, Data Science, and Education

AR: I'm going to ask some "big picture" questions in the next segment. Do you consider statistics to be a separate discipline from mathematics? Do you consider statistics education to be a distinct field from mathematics education? Do you think such distinctions are important or helpful?

LL: Great questions, Allan! I agree with those (e.g., Moore 1988; Cobb and Moore 1997; delMas 2004; De Veaux and Velleman 2008) explaining how statistics has fundamental differences from mathematics, and therefore is distinctive enough to justify its own journals, conferences, and organizations. It's totally understandable when statisticians assert that statistics *uses* mathematics but is not a *branch* of mathematics and Dennis Pearl likes to quip that mathematics is actually a deterministic special case of statistics! That said, my three university full-time appointments to date have all been in departments that included mathematicians, statisticians, and mathematics/statistics educators, and I've appreciated readily having cross-disciplinary conversations. For example, such a hallway conversation with mathematician Steve Leth helped as I wrote my piece on the Birthday Problem (Lesser 1999). Also, it's interesting now how data science sparks authentic collaborations between statisticians and some types of mathematicians, so I predict we'll work and learn together even more.

When it comes to education, I believe statistics teaching should be done by someone who has had meaningful experience with data or who has at least engaged with a critical mass of professional development resources and workshops (such as those offered by CAUSE) and it has been very important and valuable for statistics education to have its own journals, conferences, and organizations so that statistics education can make progress at a healthy rate. Still, we learn from each field's experiences and find parallels (e.g., Lock and Lock 1993). It's good that ASA already has a precedent of joint committees, activities, and publications with NCTM or with MAA.

When it comes to education research, the difference is much less because I can't think offhand of a research method a mathematics education researcher might use that could not be used in a statistics education research context. There was a time when that was not clear, though. Very early in my career, I had a statistics education paper discouraged by a journal editor simply because it was qualitative research, but qualitative research not long after that became broadly accepted in statistics education and even yielded a focus issue [the November 2010 issue of *Statistics Education Research Journal*].

And when it comes to me, having one foot (or partial foot, since about $^3/_4$ of my scholarship could be classified as statistics education) in mathematics education and in statistics education has been stimulating because I enjoy making bridges and cross-pollinating—as do several terrific colleagues like Hollylynne Lee, Alejandra Sorto, Randy Groth, Mike Shaughnessy, Jennifer Kaplan, etc. Sometimes I write the only statistics part of a math education work, such as my Simpson's paradox chapter (Lesser 2001) for an NCTM book on representations or my statistics chapter (Lesser in press) for a book called *Teaching Mathematics to English Language Learners*. And in the other direction, I already mentioned bringing the research on social

justice and on English learners from math education over to statistics education. It's fun finding counterparts and synergies, and being literate in both domains has informed my professional committee work over the years for ASA, CAUSE, and NCTM and my work as a journal editor or reviewer. The main challenge is that the number of interesting and worthy conferences and organizations I could potentially be part of exceeds my available time and money, so I have to take turns with some of them. For example, I haven't missed an USCOTS since 2006, but I go only sometimes to most other conferences such as NCTM, JMM, and JSM.

AR: You've anticipated my next question by slipping the phrase "data science" into your response. What do you think of the data science craze? Has the emergence of data science changed your teaching at all? What effects do you foresee, if any, on statistics education from the data science phenomenon?

LL: It was obviously not a phenomenon when I took my graduate courses in statistics three decades ago, and though I wrote a data science song with Michael Posner, I have much to learn about this area to fully incorporate it into courses I teach or confidently predict the trajectory of its effects on our field. I'll just make a lesser conjecture that data science may inspire at least some statistics courses to be a bit less about applying a list of procedures to simplified datasets and more about starting with a messier, more open-ended data set, using more visualizations, and letting that spark the questions and selection of methods.

I met with well-known mathematics educator Jo Boaler when she came to my campus this January and she made a compelling case that the high school curriculum would be much more engaging and relevant by incorporating data science rather than just focusing only on the traditional climb of Algebra II to Precalculus to Calculus. She maintained it would also be more equitable because data science has a "lower floor" for entry, while only some students get tracked to have access to the calculus pathway. My department at UTEP is actually starting a PhD program in data science in 2021, so I'm looking forward to opportunities to learn more.

AR: Speaking of high school mathematics curriculum, what do you think of how it has changed with regard to data and probability and statistics over the past three decades? Have you noticed a change in the preparation of undergraduates that you teach? Has your teaching of prospective teachers changed in response to curricular changes at K-12 levels?

LL: It's great that more data and statistics have been added to the curriculum, but there are areas that still need more integration or fine-tuning (e.g., Groth 2019) and I trust that the revision team for the *Pre-K-12 GAISE Report* is looking at that. With the undergraduates I teach, it seems that they more often arrive with exposure to certain topics, but not necessarily with explorations and conceptual emphasis. So with time saved by not having to introduce some topics from scratch, I try to focus more on concepts, connections, and projects. Sometimes when I notice pre-service teachers' background knowledge gaps, I help them safely explore and address them by asking "How do you think a middle school student might interpret this?" I've enjoyed teaching a statistics course for pre-service middle school teachers using a book (Perkowski and Perkowski 2007) that makes explicit curriculum connections (but from a more advanced standpoint, of course) by including excerpts from widely used middle school textbooks. This helped the class feel the course was more relevant and made it easier to incorporate not just content knowledge, but also pedagogical knowledge, pedagogical content knowledge, and technological pedagogical content knowledge (say that 3 times fast!).

AR: Can you provide specific examples of those last two terms?

LL: Sure. Sometimes people or institutions unduly compartmentalize and tell students to learn generic pedagogy methods from the College of Education and mathematics/statistics content from their Department of Mathematical Sciences. But pedagogical content knowledge is more than the sum of these domains and often does not get covered in either building. For example, just because you know statistics content and general teaching techniques does not ensure you know what misconceptions are common for a particular statistics topic and what interventions or activities are most likely to help those misconceptions get identified and resolved. (We know it's not enough just to tell students to avoid a misconception.) Technological pedagogical content knowledge adds awareness of what forms of technology are most likely to help explore particular concepts and how to scaffold the use of the technology during the exploration. Hollylynne is the real expert in this area, but I also wrote a few brief papers (e.g., Lesser and Groth 2009; Sorto and Lesser 2010).

In case it helps, I'll give a concrete illustration adapted from Lesser and Groth (2009, pp. 149–150) on the chance of an event happening at least once in a fixed number of opportunities. From a statistics content perspective, this involves recognizing that it is easier to subtract from 1 the probability of the event's complement. Pedagogical content knowledge tells us that students tend to underestimate these disjunctive probabilities. Pedagogical knowledge tells us that misconceptions are more likely to be noticed and resolved in a lasting way if students write down their prediction to a question before doing an exploration, and then reflect on the (conflicting) result.

With the specific context of the Birthday Problem, for example, the traditional textbook approach involved multiplying a long string of fractions, but technological pedagogical content knowledge tells us that a simulation or a spreadsheet approach (Lesser 1999) can more readily yield the answer, as well as generate an excellent "opportunities-based" approximation that adds intuition. And, if a student predicted it would take N people to have a 50% chance of at least one birthday match, technology could be used to quickly generate many sets of N birthdays and then show what percentage of those sets had at least one match. Alternatively, students can be asked to predict the probability of at least one match in a group of 23 people and then do simulations with technology such as a graphing calculator (Flores and Cantu 2012). By the way, pedagogical content knowledge tells us how to detect and address students confusing the Birthday Problem (*any* two people matching) with the Birthmate Problem (someone matching with *me*).

AR: That's very helpful, thanks. You mentioned Jo Boaler earlier. She and Steven Levitt, economist and coauthor of Freakonomics, *have recently argued that the high school mathematics curriculum in the United States should be re-structured around the concept of data fluency. What do you think of this idea? (The op-ed appears here: https://www.latimes.com/opinion/story/2019-10-23/math-high-school-algebra-data-statistics. The podcast episode can be found here: http://freakonomics.com/podcast/math-curriculum/.)*

LL: Hmmm…. my short answer is that I agree the curriculum should be reworked to include more emphasis on data and such sentiments are not new. Prominent mathematician Art Benjamin argued in a 2009 TED talk that the summit of high school curriculum should be statistics, not calculus: *https://www.ted.com/talks/arthur_benjamin_teach_statistics_before_calculus?language=en*.

The devil is in the details—such as whether it's better to create self-contained data fluency courses to replace much of the current high school math sequence or whether it's better instead to integrate data fluency into current mathematics and non-mathematics courses, not unlike "quantitative reasoning across the curriculum." After all, some statistics topics have already worked their way into the traditional math sequence (e.g., line of fit in high school algebra) and it's possible to do more of that. If it's the former, then the question is what courses must get deleted or merged to free up the room—I'm reminded of "Letting Go to Grow," the theme of USCOTS 2009 where you and Beth Chance debated what to remove from Stats 101. For example, I imagine we'd agree that some fluency with algebra is still needed, but the overlap Algebra II has with Algebra I (and with Precalculus, for that matter) suggests room for consolidation, especially by sticking to essentials.

In any case, I hope we focus not just on curriculum but also on instruction. Sometimes it's not so much that a topic is irrelevant as that the way it's taught is irrelevant. Many topics are still taught with contrived context, oversimplified numbers/expressions, a focus on rote procedures rather than sustained creative problem solving, and no more than one representation. One of many attractive things about Boaler's project (*youcubed.org*) is that she maintains any "boring" algebra procedure can be taught visually and creatively. We also have to look at assessment. When it comes to large-scale assessment, what tends to be assessed is too often simply what's easier to assess, not what's more important to assess. It takes much less time and training for graders to decide if a student, say, correctly factored a polynomial than whether the student reasonably worked with a messy real-world data set. So there needs to be a change of culture with corresponding supporting resources.

All that said, I'm not sure our arguments should lean so heavily on current job market trends. After all, if money should be our main guide, most of us would choose industry, not academia. An undue utilitarian emphasis also denies how a more theoretical area of mathematical or statistical sciences can overnight become a hot applied area. And given challenges to our nation's democracy, I would argue that it's no less vital to prepare ourselves to be effective citizens than to be wage earners. But a focus on citizenship still leads us to need more statistics and data science as H. G. Wells predicted almost a century ago!

AR: I'm sure you're aware of the special issue of The American Statistician *titled "Statistical Inference in the 21st Century: A World Beyond $p < 0.05$." In what ways do you think we should change the teaching of statistical inference?*

LL: I'm not sure offhand I can add much wisdom to what that *TAS* issue already said—I should be asking *you* this question! For some simple takeaways, I would just say that it does seem clear we need to teach students to report not an inequality but the actual *p*-value and to interpret that value in its real-world context and provide some type of effect size. One of our Project SMILES songs ("Everything's Unusual") addresses a big limitation of statistical significance—namely, that for a big enough sample size, *everything* is statistically significant! You've probably heard the quip that the word *significant* should be used not as statistical pronouncement but as power of attorney ("sign if I can't").

Moving away from dichotomous-rule thinking (e.g., by using compatibility intervals instead of confidence intervals) and embracing context and the role of uncertainty forces us to acknowledge how the practice of statistics has never been free of judgment (Huberty 2000). One challenge may be that students in their first (or only) course that involves inference may not have the time or mathematical maturity in that course to handle all of the varied approaches proposed in that *TAS* issue to adequately explore the meaning and robustness of the *p*-value. Since it's not satisfying to give students more "do not" statements without offering alternative methods and language they *can* use, inertia probably keeps many instructors just continuing to teach as they were taught.

Of course, once most instructors are using a textbook that substantially and accessibly incorporates the philosophy of that *TAS* issue, then the baseline of teaching will change. It's a challenge because we are not always careful and consistent in our language about significance. For example, there's a well-regarded statistics textbook I grabbed off my shelf that does good things like recommending the reporting of the actual *p*-value and distinguishing between statistical and practical significance, but then in an exercise commits a pet peeve noted by Jeff Witmer (Rossman and Witmer 2019) by essentially saying "We have evidence that the (population) means are significantly different" instead of the preferred "We have significant evidence that the (population) means are different."

Ultimately, Bayesian thinking may play a bigger role. And perhaps there is a lesson to be learned with how qualitative research came to be accepted in that people realized that aspects of qualitative research are unavoidably subjective, but that it is the most authentic approach for many research questions and there are many strategies to ensure the process has rigor (e.g., see the table in Reid, Robinson, and Bunsen 1995). And maybe the struggle to transcend bright-line thinking parallels our earlier discussion on high school curriculum about how we tend toward assessing what is easier to assess even if that's not aligned with the more nuanced understanding that students should have.

Pop Quiz

AR: Let's start the "pop quiz" portion of the interview, where I will ask a series of unrelated questions and will request that

you keep your responses brief. First, please tell us about your family.

LL: I've been married since 1997 to Laurie Davis, who supports my creativity and career in so many ways and whose business Brain Plus Manual Therapy deeply integrates her backgrounds in neuroscience research and massage therapy. We're blessed with a son Judah who is majoring in computer engineering at the University of Maryland and has two refereed papers in STEM education. As for family of origin, my sister Lori practices intellectual property law in New York and my mom's still alive and well in Houston, the city where I grew up.

AR: What are some of your hobbies?

LL: I doubt it will be surprising to hear that my most developed hobby is songwriting. I've been fortunate to find ways to do some of it with professional quality (e.g., my just-released album) or integrate it (via STEM songs) into my full-time academic job. And I really lucked out when my all-time songwriting hero David Wilcox parked at my house for a week the Airstream trailer he was using to take his family on a two-year cross-country tour, but that's another story. I also like playing guitar, writing poetry (*https://larrylesser.com/poet-larry-ate/*), traveling, hiking, and just hanging out with friends, family, and our hairless rescue dogs Kelev and Mo with their delightful but very different personalities.

AR: What are some recent books that you have read?

LL: Because my spare time is rare and fragmented, I seldom get through entire books in a short time and so I tend toward material with self-contained chunks I can read just before bed like an article from a periodical or a poem from a poetry book. The stack on my nightstand now has Hans Rosling's *Factfulness*, Sasha Pimentel's *For Want of Water, and Other Poems*, the new issue of *The Sun*, and some articles I printed out from the current *JSE* and *Journal of Humanistic Mathematics*.

AR: Please name three favorite travel destinations, one that you visited for professional reasons, one that you visited for pleasure, and the one that still remains on your bucket list.

LL: Laurie and I were enchanted by the beauty of the rainforest, beaches, and volcanos of Hawai'i—a magical personal vacation that unexpectedly yielded moments of disciplinary insight (Lesser 2016a). My favorite professional trip would be Slovenia for ICOTS 2010. The conference was great, Ljubljana was very pedestrian-friendly, the Postojna Caves were beautiful, and I had great conversations and meals at the home of a wonderful local family I connected with before the conference (see photo at *http://sigmaa.maa.org/stat-ed/ICOTS/ICOTS8_Reports.htm*). You learn much from quality time with locals! On my bucket list is to spend extended time in Israel—I've actually visited before (most of my wife's relatives live there and I gave a talk at the Technion), but not long enough to experience all of its beauty and rhythms.

AR: Please tell us something about you that is likely to surprise JSE *readers.*

LL: Well, in 1984 my friend Jed Dennis and I were spending a Houston summer afternoon at a YMCA and he recognized Charles Barkley shooting baskets by himself and we decided it would be fun to challenge "The Round Mound of Rebound" to a 2-on-1 game, figuring we'd win by ganging up on defense and spreading the floor on offense. But it quickly became clear that we couldn't stop him from scoring or rebounding and even on offense our 2-on-1 advantage was no match for his height, reach, bulk, strength, speed, and anticipation, and he won quite decisively and graciously, without full effort. It was a blast—how often does one get to play a superstar destined for the Basketball Hall of Fame?

AR: Here is a fanciful question: You can travel in time to observe what's going on in the world for one day. What time would you travel to—in the past or the future—and why?

LL: If I traveled to the past, I'd have a hard time observing without intervening (cue the Dan Bern song "God Said No"). So I guess I'd go a century into the future and hope to find a still-habitable planet where we successfully met challenges of climate change, food insecurity, terrorism, global conflict, and poverty—and where that world's citizens would all have data fluency, of course!

AR: Here's another silly one: *You can have dinner anywhere in the world (all expenses paid) with three companions, but the dinner conversation must revolve around statistics education. Who would you invite, and where would you eat?*

LL: I'd reserve a table at The Eucalyptus in the Artist Quarter of Jerusalem and invite Joan Garfield (with whom I've enjoyed many great dinner conversations, from Minneapolis to Marrakech), David Moore (another pioneer in our field, and I'd love to tap his brain as well as thank him again for entrusting me to update his fantastic statistics chapters for new editions of a math for liberal arts textbook), and my longest collaborator Dennis Pearl (who has a great sense of humor and perspective in so many areas).

AR: Let's collect some data: Do you consider yourself an early bird or night owl? On what day of the week were you born? How many of the 50 states have you set foot in? How many miles do you live from your birthplace?

LL: night owl (either way, statistics educators get *Z*'s); Wednesday; 37; 2152.

Conclusions

AR: Thanks very much for taking the time for this interview, Larry, and for putting so much thought into your responses. I have two questions to follow this one, but let me first ask whether there's anything that you would have liked me to ask that I have not asked.

LL: You're so welcome, Allan, and thank *you* for this fun and meaningful chance to reflect on my trajectory. I can think of only a few things that didn't come up, such as my journal editorial

work, lottery education outreach, and directing my university's teaching center.

AR: Those all sound very interesting. Please tell us about each one.

LL: I had much satisfaction and growth from two 3-year Associate Editor terms for *JSE* and a 3-year Assistant Editor term for *SERJ*. It was daunting to follow Beth Chance in that latter role because she set an incredibly high bar for copy-editing, layout, and proofreading, but she gave me the mentoring I needed to do it. I've also done editorial work for refereed journals in mathematics education, serving many years as an Associate Editor for *Journal of Mathematics and Culture* and for *Texas Mathematics Teacher*. Finally, I was a founding coeditor (and am now the Associate Editor) of *Teaching for Excellence and Equity in Mathematics*, the refereed journal of the NCTM affiliate organization TODOS: Mathematics for ALL, and it's wonderful to have that journal enter its second decade maintaining distinctive features such as having articles accompanied by pre-reading and post-reading questions for professional development. It's sometimes hard to turn off my "editor eye," which some people find helpful and some probably find annoying!

I was a grad student when the Texas Lottery launched and it became clear many Texans had an incomplete grasp of its underlying probability—and psychology. So I felt it was my statistical civic duty to help people make more informed choices about how or whether to play. But I had no idea the one-shot adult education class I created and first taught in 1993 would go viral: a story spanning 3 column feet in the *Austin American-Statesman* got picked up by the Associated Press and led to coverage over that weekend on CNN! That media wave quickly taught me to tailor content for a broader audience, to have sound bites and concrete everyday analogies ready, and to know when to reframe an interviewer question. I get to apply those lessons in print, TV, and radio interview requests that have continued to occasionally come when lotteries launch new games or amass huge jackpots. To support this outreach, I made a webpage (*https://larrylesser.com/lottery/*) that compiles my related educator articles and my song "The Gambler" I mentioned earlier. The lottery education work made me open to other statistics education outreach, ranging from writing an issue about polling for the syndicated education supplement *The Mini Page* (never thought I'd write for an audience of 20 million people in over 500 newspapers!) to teaching statistics to a live audience of elementary school students on one of the episodes I did of a children's educational TV show on a regional PBS station: *https://www.youtube.com/watch?v=iVeCN6dTvzo&list=PLdfaHtJTO4LJZfSgu2Ztvn3aI6R8B1giR&index=5&t=0s*.

I never thought I wanted to pursue administration, but it ended up coming to me. I was a supporting faculty associate for UTEP's campus-wide teaching center in 2013 when its longtime director had to step down to help his shorthanded department. As the faculty member working most closely with him, I was tapped for what turned into three years directing the center before it got replaced by a larger structure with several other foci. It's not easy promoting beyond the choir a culture of teaching in an environment so focused on raising its research profile because too many people view teaching and research in a zero-sum way that inevitably values teaching less. I genuinely enjoyed creating and delivering workshops and new instructor trainings and school year kickoff and wrapup events, chairing an annual teaching conference attended by over 200 people from several countries, finding ways to include more stakeholder groups, and launching resources for formative faculty feedback, peer observation, scholarship of teaching and learning, and a searchable database of local pedagogical expertise. Like John Tukey's quote about statisticians, I found that the best thing about being a teaching center director is that you get to play in everyone's backyard and some of the most meaningful moments were not just the large public events but the requested individual and small-group teaching consultations I did with instructors from varied disciplines. I'll always cherish how good it felt to help build campus community and I also loved the wonderful national community of teaching center directors (like Marsha Lovett!) at POD Network conferences.

AR: I think many faculty consider editorial and administrative work to be necessary but undesirable, so that's great that you have not only taken on these roles but enjoyed them. My penultimate question is: Of your many contributions and accomplishments in statistics education, of which one are you most proud?

LL: With respect to the first part, I'd note that editorial and administrative work need not be so at odds with the core work we do. Doing editorial work (or even serving as a reviewer) is a great way to keep up with new trends and methodologies in the field, make new connections with wonderful kindred spirits, gain more insight into how papers meet high standards, and finally internalize those finer points of rhetoric, grammar, and style. And though I still love research and teaching too much to imagine myself being a full-time administrator, the half-time directing of the teaching center was a good fit because it had a fairly self-contained focus that aligned with my experiences of doing research and professional development in STEM education. And so I was able to apply my statistics education background to my new role and I also learned things in that new role that I could apply later to my statistics education work. So *JSE* readers should not be quick to assume that editorial or administrative work can't be a win-win!

Okay, back to your question—I'll pick my paper with Matthew Winsor (Lesser and Winsor 2009) because of how I grew and stretched myself to weave together so many different people and elements to yield the field's first major research paper on English learners in statistics. I love how that paper was not just a career milestone (e.g., my first of what has been several papers in our field's most selective journal) but also a source of genuine implications for curriculum and instruction, as I discussed earlier.

I have to note that while an interview about my work can't avoid lots of talking about individual accomplishments, I'm quite clear that it takes a village. I'm so grateful to work in a field that's truly a community where meaningful roles are available to people of all ranks and where newcomers are welcomed, collaboration is supported, inclusion is sought, losses are mourned, successes are celebrated, and people are valued as people. As I approach my career's last decade, I'll keep seeking ways to pay forward the mentoring, inspiration, and collegiality I've received

and do my part to further humanize our discipline and advance our community.

AR: Let's conclude by offering advice for those new to our profession, with regard to teaching or education research.

LL: Whether someone is joining us from a background in mathematics education, statistics, data science, social science, business, or something else, here are some bits of advice I'd say, beyond websites like *https://www.CAUSEweb.org/cause/research/getting-started* and *https://larrylesser.com/welcome-to-statistics-education/*.

This is not the kind of community where you have to pay your dues for 20 years before you have real opportunities to contribute. Go ahead and connect with people in the field whose work inspires you—we're a friendly bunch!—and attend conferences and webinars. (For example, my collaboration with Dennis Pearl started from conversations at a JSM, my collaboration with Megan Mocko was sparked by her 2012 CAUSE webinar, and several other collaborations were launched at USCOTS meetings.) Get involved with CAUSE and have your institution become an institutional member of CAUSE if it isn't already.

Offer to be a reviewer for a statistics education conference or journal—for as little as a few hours per year, the process not only yields a CV entry for professional service, but also yields insight in what will improve the chance of *your* papers getting accepted. For example, while I've published a lot in *JSE*, that all started after I completed a three-year term on its Editorial Board. (For more on the importance of reviews, see Heid and Zbiek (2009).) Be persistent, just as we want our students to be when they don't immediately understand something. Some of my papers needed huge revision or submission to a second or even third journal before being accepted and in all cases I was glad the original submission wasn't what got published!

Be true to your whole self. My backgrounds as a math educator, high school teacher, teaching center director, state agency statistician, songwriter, etc., have all ended up informing things I've done as a statistics educator. Even interests where I wouldn't claim highly-developed expertise have yielded articles (e.g., Lesser 2017b).

Be open to reaching varied audiences in varied ways—for example, often a project can yield a research paper in *SERJ*, *JSE*, or *TISE*, and also a more activity/teacher-oriented article for *Teaching Statistics* or *Statistics Teacher* or for a journal not limited to statistics education like *Mathematics Teacher: Learning and Teaching PK-12.* And that same project may also position you to offer a webinar, make a video, do public outreach, or pursue external funding. There are many possibilities and as Jo Boaler might say, our field has a low floor and high ceiling!

AR: Readers might enjoy a 90-sec rap that provides a lively summary of Larry's career trajectory: https://www.youtube.com/watch?v=sFizdFK09l8.

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