"WITH GREAT POWER COMES GREAT RESPONSIBILITY"

HARNESSING THE EXTRAORDINARY POWER OF STATISTICS

ABSTRACT

THE CALL FOR BANNING P-VALUES BY THE EDITORS OF A NOTED SCIENTIFIC JOURNAL IN 2015 CONTINUES TO FRUSTRATE STATISTICIANS. WHILE SUCH CONTROVERSIES TYPICALLY SURFACE AROUND A SPECIFIC STATISTICAL CONCEPT SUCH AS P-VALUES, THEY ARE SYMPTOMS OF A LARGER PROBLEM THAT INCLUDES COMMUNICATION GAPS AND MISTRUST OF STATISTICS IN THE SCIENTIFIC/BUSINESS COMMUNITIES.

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The call for banning p-values by the editors of a noted scientific journal in 2015 continues to frustrate statisticians. While such controversies typically surface around a specific statistical concept such as p-values, they are symptoms of a larger problem that includes communication gaps and mistrust of statistics in the scientific/business communities. Ironically, the call for the p-value ban was motivated by the widespread misuse of the p-values in the name of science. Statisticians have an obligation to the discipline of statistics and to the fields of application to promote statistical best practices while discouraging misuse and abuse that come from poor understanding of statistical tools.

At the Joint Statistical Meetings held in Chicago in August 2016, a group of panelists from varying statistical backgrounds—Daniel Mowrey (DM), Jonathan Potts (JP), Susan Spruill (SS), and Walter Stroup (WS), moderated by Michiko Wolcott (MW)—deliberated on the concept that the p-value is not the problem but rather a symptom of other problems, namely the lack of early involvement by the statisticians as collaborators and by gaps in education on the importance and utility of correctly interpreting statistical analyses. The following is an interview with the panelists.

MW: To start, what are the key perceptions about statistics and statisticians in the world around us?

DM: To the non-statistician, statistics goes hand in hand with sports or anything associated with numbers. The person who is responsible for summarizing these numbers is, of course, the statistician. People tend to fall into two camps with respect to statistics: 1) statistics can be useful in proving a point or 2) statistics are almost the lowest thing on the earth. The expression "lies, damned lies, and statistics" summarizes these two points quite nicely.

The scientific community probably views our discipline similar to the Merriam-Webster definition: A branch of mathematics dealing with the collection, analysis, interpretation, and presentation of masses of numerical data. The American Statistical Association (ASA) describes statistics as the science of learning from data, and of measuring, controlling and communicating uncertainty; thereby providing the navigation essential for controlling the course of scientific and social advances.

There are many interpretations associated with statistics. However, I believe statisticians would like to convey to everyone that it is a fascinating science that relates to almost anything that someone does.

NONE OF THE DEFINITIONS OR PERCEPTIONS PROBABLY MATTER IF STATISTICIANS ARE TREATED AS SCIENTISTS WORKING WITH OTHER SCIENTISTS.

Statisticians have been described as number crunchers, numerologists, and numbers people. Merriam-Webster states: the statistician is an expert in the preparation and analysis of statistics. From ASA, a statistician is a person who applies statistical thinking and methods to a wide variety of scientific, social and business endeavors. The ASA definition is a little more specific than other definitions but the term "statistical thinking" does raise questions which have been addressed over the years.

None of the definitions or perceptions probably matter if statisticians are treated as scientists working with other scientists.

MW: How have the roles of the statistician and the statistician's circle of collaboration changed in the last 10-20 years? What remains the same?

SS: I have certainly experienced changes over time, but they may be more situational than temporal. When I started out as a statistician, in 1984, I was part of a team at the North Carolina State University (NCSU) Agricultural Research Service. I interacted with the scientists daily and had a lot of influence regarding experimental design and data collection. I was often asked to coauthor publications and invited to attend and speak at conferences and workshops. It was the ultimate in collaboration.

I left the university environment in the early 1990's and took a position as a senior statistician with a Clinical Research Organization (CRO). This move changed the way I collaborated. The pharmaceutical companies had the statistical "brains" and needed the CROs as their "worker bees." So, being able to follow others' leads was key to success as a statistician in the early CRO business.

With the boom of small-to-midsize biotech companies in the mid-to-late 1990s, the focus of CRO statisticians began to shift from being the extra personnel in large pharmaceutical companies to becoming the statistical experts for small pharmaceutical companies. When I transitioned to being the sole statistician in a small biotech company, my responsibilities shifted to strategic planning and product development. I was able to contribute my statistical expertise and to learn more about the other components of drug development, such as regulatory processes and manufacturing. Today, as a consultant, my clients expect me to give them guidance rather than hands on analyses.

MW: What are the key barriers to successful collaboration between statisticians and others? How does the current culture within statistics impact our ability to collaborate, and how does it need to change?

SS: As statistical collaborators, we should not assume every prospective collaborator wants the same thing. Phrases like "data are data" may be true, on the surface, but how you explain the results to your collaborators makes all the difference. While statisticians may be the statistical expert, the collaborator is a scientific expert. We should always be willing to work as a team to solve a problem and learn from others.

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DM: Many statisticians today want collaborators to change how they collaborate with us. However, collaborators probably don't know how to change because they only know the way they were "brought up". So maybe it is up to the statistician to make the first move by borrowing from *The Seven Habits of Highly Effective People* by Covey. Let's begin by being more proactive by having statisticians convey the same message when it comes to studies, so that collaborators don't get mixed messages on what is and what is not acceptable. Let's stress to journals that, although significance might be important in some cases, it is what is learned from following a well-designed scientific process that is more important. Let's stress the importance of beginning with the end in mind so that there is no need for guessing what to look for when the study finishes up. Let's stress the need to put first things first such as ethics, excellence, and quality. Let's think win-win with our

collaborators, so that they can see that we care about their work. Let's seek to understand the problem, listen more, and speak less. Let's work together to improve and be willing to adjust if things need to change.

MW: WHAT ARE SOME REASONS FOR THE SINGULAR FOCUS ON ANALYSIS EXECUTION TODAY? HOW HAS THE DEMOCRATIZATION OF ANALYTICS IMPACTED THIS, AND HOW DO WE BRING THE FOCUS BACK TO THE SCIENTIFIC PROCESS?

JP: The return on investment is a key reason. I think analytics was once seen as an add-on to traditional services especially in the credit analytics world. Now that there has been a substantial investment in big data and analytics, many businesses are looking for a monetary return in each analysis. This can be troublesome, since not all analysis leads to a solution.

MANY BUSINESSES ARE LOOKING FOR A MONETARY RETURN IN EACH ANALYSIS. THIS CAN BE TROUBLESOME, SINCE NOT ALL ANALYSIS LEADS TO A SOLUTION.

DM: To most people, statistics or statistician still have the same meaning regardless of data science or predictive analytics. The scientific community still believes that statisticians work with data, so what has changed? Not much except the data sets are larger. However, within the statistics community, and among statisticians, there is a greater awareness about what is being done in the name of statistics and who is being classified as a statistician. Today, we have data scientists, predictive analysts, and machine analysts and others who some classify as statisticians while others would say no. It is something statistics has been struggling with because it is associated with change and not many people like to deal with change.

JP: Often, statisticians are brought on board a project after data has been collected and projections have been promised. One way to bring back the scientific process is to analyze projects that use statisticians in the pre-planning/design phase of a project versus those that did not. Hopefully, the added value can be seen immediately in the projects where statisticians were included at the beginning. Having the statistician participate in planning will make them aware of the objectives and hence be able to propose the proper analyses.

DM: When others seek the collaboration of a statistician, they generally have a problem and want statisticians to come to their rescue especially if there was not any forethought into the study design or the analysis to be conducted. The real question is: how do we change this paradigm so that their learning is a more robust scientific process that involves statisticians at the beginning of the thought process?

MW: WHAT *DO* STATISTICIANS BRING TO THE TABLE? WHAT DO OUR COLLABORATORS BRING TO THE TABLE?

SS: We are problem solvers. The collaborators bring us interesting problems, not tasks. Even apparent tasks, such as reviewing a manuscript can become a problem to solve if we can see a better experimental design or way of rewording a statement. We must always be on the lookout for how we can make the outcome better or more meaningful for the collaborator, even if the outcome may not be what they originally hoped.

JP: We all must recognize that everyone brings a different important skill set to the table. We must be willing to accept input from various angles and be flexible. Many times, collaborators (i.e. sales consultants) may have business insight into a problem which can explain possible trends in data that the statistician may question.

MW: WHAT ARE THE GAPS NOT TAUGHT IN SCHOOLS TODAY? HOW DO WE BETTER PREPARE STUDENTS?

WS: First, integration of scientific thinking (or empirical decision making) and statistical reasoning. Courses on statistical methods focus on the mechanics of methods and their technical interpretation; the hypothesis test and associated p-value is an example and is the one that originally motivated these sessions. However, these courses make little attempt to ask what the scientist or decision maker really needs to answer the question or to make a decision. Introductory courses need to do a much better job integrating these two.

Second, analysis is overemphasized compared to planning. Walt Federer once observed that most design of experiments courses are really ANOVA courses with little, if any, of the planning aspect of design. Most experienced statistical and scientific collaborators agree that statistics can add important—often crucial—contributions before any data are collected. Too often, our courses fail to reflect this. Courses that do preach "you must plan" frequently fail to teach students *how* to plan.

WE NEED TO RETHINK THE CURRICULUM OF STATISTICAL METHODS COURSES TO INCLUDE HOW TO PLAN AND HOW TO COLLABORATE.

Third, non-statistics majors and statistics majors are not taught how to be effective collaborators. Collaboration needs to be taught systematically at universities. Non-majors are not taught how to effectively work with statistical partners. Even when statistics majors are taught to consult, they are not taught key aspects of how to be an effective partner in a scientific investigation. The curriculum needs to be revamped and provide opportunities for collaboration. It needs to cover how to "think" like other scientists, or to put another way; we need to teach statistics majors how scientists think. In addition, statistics majors should be shown how to think of a statistical analysis as a means to an end (answering a scientific question) and not as an end in itself. Consulting classes tend to emphasize the human side of consulting, and statistical methods courses tend to emphasize the mechanics and supporting theory of data analysis. Both are important and should be considered essential parts of the curriculum. But a missing part is how to get inside a scientist's or decision maker's head and understand what they need. Learning how to do this—integrating what they need with what statistics can offer—is all too often a missing third element.

We need to rethink the curriculum of statistical methods courses to include how to plan and how to collaborate. People in our discipline have been doing a lot of thinking about the undergraduate introductory statistics course, and one of the distinctions they make is between formulas that teach statistical thinking and formulas that merely show how to hand calculate what people in the real world will use a computer to do. The former has learning value. The latter has no place in a statistical methods course.

Collaboration is something that you learn by doing, not by watching and listening. There are several ways one can approach collaboration. At the University of Nebraska, we partner majors and non-majors in our graduate-level design and analysis course. We have them do a project in which the non-major proposes an experiment. The major and non-major students plan the experiment and do a precision and power analysis in such a way that we can generate simulated data according to the design and anticipated mean and variance parameters the project team gives us. Then they analyze the data and do an oral and a written report. This way, they get the experience of doing a project from beginning to end. Another idea is to pair statistics graduate students with graduate students in other disciplines doing their thesis or dissertation research, both students under the supervision of their respective advisors (e.g. the statistics professor could be the outside member on the non-major's committee and vice versa). Whatever is pursued, always remember that collaboration is doing.

Faculty in statistics departments need to appreciate that planning and collaboration are critical components in research. As the line goes from a cartoon some of us are old enough to remember, "We have met the enemy and he is us." Many statistics faculty members do not fully appreciate the importance of integrating scientific and statistical thinking. Many mathematically trained faculty members are not comfortable teaching statistics as opposed to mathematical statistics. George Box once said, "We can choose to be second-rate mathematicians or first-rate scientists." I may be preaching to the choir, but our statisticians teaching methods courses need to reflect what Box obviously believed to be the right choice. All too often, they do not.

MW: To plan and collaborate, how do we better hire, train and retain faculty?

WS: University statistics departments are all over the map in terms of whether collaboration with scientists in allied disciplines is valued, supported and rewarded.

In land grant universities, there should be no question that collaborative research is a core mission of the statistics department, and faculty from statistics and collaborating disciplines should be encouraged and rewarded for team efforts that result in good science. All too often, however, this does not happen. We live in an era where single-author publications, big grant dollars as lead principal investigator, and high-profile research solely by statisticians and solely about statistical topics, are the currency of the realm. There is a need for this, but if this is all that counts, statistics risks becoming insular, at least in university research, and good science loses. In many universities, collaboration is increasingly seen as something for non-tenured faculty ("professors of practice" is the University of Nebraska term) and sometimes consulting is not even considered a legitimate faculty level activity.

> IF WE ALLOW APPLIED STATISTICS TO BE SYNONYMOUS WITH SECOND-CLASS, WE WILL HAVE A SELF-IMPOSED PROBLEM.

Often, new assistant professors get the message that collaborative research is professional suicide. If you want tenure, avoid collaboration. To some extent, this is a prejudice many of our colleagues who sit on promotion and tenure (P&T) committees share and perpetuate. If we allow applied statistics to be synonymous with second-class, we will have a self-imposed problem. Faculty cannot teach how to plan

and collaborate unless they have experience and are actively engaged in at least some interdisciplinary collaboration.

I have spent my entire career at land grant universities, so I cannot speak about what goes on at other universities with the same authority. I suspect that in many cases, courses on statistical methods are taught by instructors whose primary training is mathematics, and who may in fact be mathematics faculty. I do not think we should look down at them, but I do think that the ASA should be very proactive in providing instructors who fit this description with some form of in-service training to ensure that they teach statistical methods and scientific *reasoning* courses rather than the rote application of statistical techniques.

Finally, some years ago, the ASA put a lot of effort into guidelines for introductory statistics courses (GAISE). Each year at JSM, there are dozens of sessions on teaching introductory statistics courses to high school students and first-year college students. We need similar effort and energy put into statistical methods curriculum and courses for graduate-level scientists in training.

DM: Hiring, training, and retaining faculty is a good start to addressing some statistical deficiencies in collaboration and planning. However, what about maintaining our organizations knowledge? It has been said that an organization's knowledge is inherently bound to the organization's culture. For many years, our culture has been following sound scientific principles and trying to promote those principles to the people with whom we interact. In years past, we have had champions who promoted these scientific principles and kept them in front of our organization—G.W. Snedecor, W.G. Cochran, G.E.P. Box, J.W. Tukey, and D. F. Cox, to name a few. I am not sure those champions still exist, but we need these champions now more than ever; without them, our organization will falter and eventually fail. As we look around, do we see our statistical organizations, universities in particular, still maintaining what knowledge that they had in the past? A knowledge, which had a strong foundation in statistical principles and that guided people in being scientifically sound scientists. Will someday that knowledge become a thing of the past, maybe forgotten forever? Let's make sure that this does not happen.

MW: So, what can we do to improve planning and collaboration as individual statisticians? As a profession?

SS: We need to listen and ask questions. The statistician must be willing to read/learn more about the collaborator's field of science, so that questions and solutions can be made relevant. Collaborators desire someone who is strategic, reliable and well-spoken.

> WE SHOULD BE PROACTIVE AND UNDERSTAND THAT WE ARE ALL IN THIS TOGETHER.

We should also be proactive and understand that we are all in this together. We may want our collaborators to change how they work with us, but they may not know what that entails.

WS: We need to be active in getting our statistical methods courses right. We also need to be active in communicating with faculty in disciplines that are consumers of statistical methods what the problems are, and why and how we are revamping statistical methods courses to address them.

We need to be active in non-statistical professional societies. We should work with their leadership to agree on statistical best practices for research and publication in their journals. We should seek to understand, appreciate and address their need and we should be willing to provide continuing education.

We need to identify faculty members who "get it" and utilize their expertise to communicate to departments on campus who are consumers of statistical methods. In addition, these faculty members could present the latest developments in statistical practice, do seminars, and attend new faculty orientations.

We need P&T committee leaders who make sure the university culture is friendly to statistics faculty who collaborate. If none of the tenured university faculty are so engaged, then the university's ability to educate and train the next generation of statistical collaborators is imperiled.

Finally, many researchers say, "I would love to have a collaborating statistician on my research team. Where do I find one?" This is a real problem at colleges and universities that do not have a culture of collaboration, do not reward statistics faculty for collaboration, and/or do not have a viable consulting/collaboration infrastructure. Could the ASA develop some viable mechanism to connect researchers caught in this quandary with statistical help?

About the Panelists:

Daniel H. Mowrey served as a statistician for 36 years in the animal and human health pharmaceutical business at Eli Lilly and Company. He has worked in many scientific areas and collaborated with chemists, toxicologists, biologist, microbiologists, veterinarians, medical doctors, meat scientists, nutritionists, engineers, regulatory, safety, and quality professionals.

Jonathan Potts has spent the last 10+ years in the credit risk industry, from creating custom predictive models for the telecommunications clients at Equifax to developing credit authorization strategies for a major home improvement retailer at Citigroup. Jonathan recently transitioned to Experian where he is a Senior Data Scientist in a the newly formed Analytics on Demand vertical.

Susan Spruill is a consulting statistician with 30+ years of experience in clinical trials and regulatory requirements. An accredited professional statistician (PStat®), she also serves on the Editorial Board of Significance Magazine, published by Wiley-Blackwell on behalf of the Royal Statistical Society and the American Statistical Association.

Walter Stroup is a professor in the Department of Statistics at the University of Nebraska, Lincoln, where served as the chair from 2001-2010. An ASA Fellow, he teaches courses in design and analysis of research studies and in statistical modeling to graduate students in statistics and in a variety of disciplines that use statistics, and has collaborated with researchers in agriculture, various science disciplines, and education.

Michiko I. Wolcott is the managing partner and principal consultant of Msight Analytics, a management consulting firm specializing in data and analytics. Backed by twenty years of experience in leading analytical project execution and delivery worldwide, she helps organizations of all type and sizes in the development and implementation of enterprise capability and effectiveness in data and analytics.