WHAT IS STATISTICS? EXAMINING THE DISCIPLINARY BELIEFS OF STATISTICS TEACHING ASSISTANTS

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Research has shown that teachers' pedagogical decisions are deeply influenced by their own disciplinary conceptualizations and beliefs. As a dynamically evolving discipline, statistics evokes a wide range of perspectives, ranging from a rather applied, interdisciplinary approach to a deeply theoretical, mathematical understanding. We recognize that incoming statistics Teaching Assistants (TAs) enter their graduate programs with varied academic backgrounds and disciplinary experiences that likely influence their own approach to teaching statistics and uptake of department training. We investigate how statistics TAs' previous experiences shape their incoming disciplinary and pedagogical beliefs for statistics. We share survey and interview findings from seven statistics TAs new to their graduate programs.

BACKGROUND

TAs represent a unique subset of instructors, switching back and forth between the roles of teacher and student. TAs often value more student-centered classrooms, but their visions are constrained to their own experiences as students, which in mathematics is often teacher-centered (DeFranco & McGivney-Burrelle, 2001). A considerable number of statistics TAs likewise value reform-oriented practices, but report using lecture as their primary instructional method (Justice, Garfield, & Zieffler, 2017). Many struggle to think about introductory-level problems conceptually, instead eliciting more procedurally-based methods they use in their graduate courses (Dolor, 2017; Noll, 2011). TAs teaching from a textbook may also struggle to view their course beyond mastery of problems rather than as the development of central concepts (Green, 2010).

This report represents initial findings from a larger study that seeks to understand how first-year TAs form and refine a *statistics education philosophy*, which we describe as the set of central beliefs shaping pedagogical decisions for teaching statistics. We organize this philosophy around several components adapted from Ernest's (1991) mathematics education philosophy framework: a) Conceptualization of statistics, b) Aims of an introductory statistics course, and c) Models for teaching and learning statistics. This involves how TAs consider what it means to do statistics, articulate what students should learn in an introductory course, and describe the learning environment they wish to create in their classrooms. While we are ultimately interested in how this philosophy develops and influences teaching practice, this paper focuses on capturing how TAs' incoming experiences influence the formative development of this philosophy.

METHOD

This study took place in a statistics department with 200 graduate students and 62 TAs, housed in a large, public university in the U.S. A new cohort of 12 graduate statistics students who received teaching assistantships were asked to complete a survey and entrance interview if they had interest in being solo instructors the following year. Table 1 displays background information about the seven TAs who elected to complete the survey and interview.

The survey contained 23 Likert-scale items with 5 options assessing participants' thoughts about the teaching and learning of statistics, 12 items about their self-efficacy if they had to teach tomorrow, and one item asking what proportion of class time they would spend on various instructional strategies (e.g., lecturing/demonstrating, activities, individual problem solving, tests/quizzes, other). Some items were adapted from the Statistics Teaching Inventory (STI) (Zieffler, Park, Garfield, Delmas, & Bjornsdottir, 2012), the Graduate Student STI (Justice et al., 2017). Original items were reviewed by four published researchers of mathematics and statistics TAs. A subsequent interview served to assess TAs' conceptualization of statistics, follow-up on their survey responses, and inquire about their prior relevant experiences as students, scholars, and practitioners of statistics. Interviews were framed as a casual conversation in a campus coffee shop,

with each interview beginning with informal questions, like the TA's first impressions of their new city or their professors. The interview proceeded in a semi-structured format with the interviewer asking open questions and following-up as necessary. Interviews ranged from 25-45 minutes in length.

Table 1 Participants

Pseudonym	Nationality	Degree Program	Teaching Experience	Highest Degree
Kathy	U.S.	PhD	Undergraduate TA	B.S. Math & Health
Brad	U.S.	PhD	Graduate TA, Lecturer	M.S. Statistics
Wei	Chinese	PhD	None	M.S. Statistics
Li	Chinese	PhD	None	B.S. Math
Mindy	U.S.	Masters	None	B.S. Math
Sahil	Indian	PhD	None	M.S. Statistics
Dennis	South Korean	PhD	None	B.S. Math

Survey responses were analyzed in terms of identifying similarities and differences across participants. After transcribing relevant portions of the interviews, we used participants' definitions of statistics and stated disciplinary and pedagogical beliefs related to an introductory statistics course to compare and contrast cases. We synthesized the responses for each TA to describe their initial statistics education philosophy. Finally, transcript segments regarding each participant's previous experiences were considered in light of his or her survey responses and stated beliefs to understand how experience influenced the formation of this philosophy.

RESULTS

We highlight three survey items that elicited considerable variability in responses and represent divergence in beliefs about statistics teaching and learning. In Table 2, response of "1" represented "strongly disagree" and a response of "5" represented "strongly agree." Brad stood out from the other participants, agreeing that students did *not* necessarily need to learn the mathematics behind methods, while all other participants strongly disagreed with that statement. Brad, Sahil, and Li valued deeper coverage of topics, even if it meant cutting topics from the course. Kathy, Mindy, and Sahil all strongly agreed that students should frequently complete calculations using formulas, while Brad and Wei somewhat disagreed.

Table 2 Responses from Subset of Key Items

	Kathy	*Wei*	*Mindy*	*Brad*	*Sahil*	*Li*	*Dennis*
Students do not need to learn the mathematics behind statistical methods as long as they can use the methods properly and interpret results correctly.	1	1	1	4	1	1	1
Most students should learn more topics in less detail instead of fewer topics in more detail.	4	3	4	2	1	2	3
The course should require students to frequently calculate using formulas (by hand or with calculator).	5	2	5	2	5	4	3

Statistics Education Philosophy Profiles

Synthesizing findings from both survey and interview data, we briefly describe several statistics education philosophy profiles that emerged from the data. We do not present these philosophies as a comprehensive list representative of all TAs. Nonetheless, the profiles we have captured show variation in beliefs across TAs and demonstrate important distinctions in how new TAs with different backgrounds may view statistics education in very different lights.

Brad and Sahil emerged from the interviews as having the most well-developed philosophies. Each had completed an MS degree in statistics prior to entering the Ph.D. program and expressed strong interest in teaching. Additionally, Brad had previous teaching experience and extensive work experience. Brad and Sahil articulated a disciplinary vision that viewed statistics as unique. They valued a course that addressed fewer topics with more depth, advocating for a focus on overarching themes rather than statistical tests. Primary disagreements were rooted in whether they believed the course should be crafting informed citizens or scholars.

We describe Brad's philosophy profile as *Promoting Statistical Literacy through Hands-on Engagement*. Brad defined statistics as "the science and study of data," describing statistics as a discipline emerging from the premise that "data vary." He was the most ardent supporter of using web-based applets and simulations in the classroom to immerse students in the art of statistics. He viewed active learning as primarily promoting literacy, familiarity, and citizen-engagement in statistics. When asked why non-majors should take an introductory course, he responded:

> "[Students] think, 'Oh I'm never going to need this stuff,' but that's not true, especially if you go work for a company. Because these companies have a lot of data, and a lot of people working on the data, and a lot of people who don't work on the data, but need to know it enough to at least make these decisions."

He also pointed out that statistics can be used to mislead the average person, and that this course should arm students with basic knowledge to avoid being manipulated or lied to.

We describe Sahil's philosophy profile as *Promoting Statistical Reasoning through Mathematical Understanding.* Sahil defined statistics as "the mathematical approach to deal with data to answer the questions related to the data." When asked how he distinguished mathematics and statistics, Sahil explained, "I'd like to say statistics…is not exactly a subset of mathematics, but partially… like it uses mathematics and it helps other subjects to deal with things that they cannot deal with easily from their own knowledge." Sahil viewed introductory course aims primarily as developing students' foundational understanding of the mathematical/theoretical basis. When asked what he thought non-majors should learn in an introductory course, he listed basic probability, basic distribution theory, basic inference, and sample surveys.

Both Kathy and Mindy believed statistics had a unique identity, but struggled to articulate this unique identity. They both described statistics essentially as the marriage of mathematics with application. We describe Kathy and Mindy's philosophy profile as *Promoting Application of Mathematical Methods through Extensive Practice*. Kathy described statistics as being similar to mathematics in there being "a process and a right answer." Likewise, Mindy described statistics as applications of theory, but did not know how to describe this theory as something besides simply mathematics. Mindy advocated for having students regularly work through example problems and even come up to the board to work them out, similar to Kathy's vision of students regularly working through practice problems in small groups in class. Both valued application as a primary aim, but saw this being accomplished through consistent practice with mathematical calculations.

Li's responses were difficult to capture as a developed profile. The interview illuminated conflicting ideas in his own mind about what it means to do statistics for different people and the competing priorities at play. His responses expressed an awareness of statistics being deeper than its applications, but he stated that he did not have enough exposure to statistics yet to articulate that. When asked to weigh three potential emphases for an introductory statistics course—statistical literacy, mathematical foundations, or conducting statistical investigations—Li responded, "I really want to agree with [mathematical foundations], but I shouldn't. I should agree with [literacy], it's perfect for an introduction course…with [mathematical foundations]...it's pretty personal, I really want students, everyone to have solid math knowledge and math skills." It seemed as though the interview itself was a turning point for him in reorganizing his philosophy.

Survey and interview responses from Dennis and Wei were less consistent than those of the other TAs. For example, when asked how he would distinguish between mathematics and statistics courses, Wei responded that they are in practice quite identical, that both primarily involve learning facts through listening to lectures. On the survey, however, Wei disagreed with the statement that students learn more from a good lecture than a good activity, and he agreed that students' grades should be based primarily on projects, presentations, and group assignments rather than tests,

quizzes, and individually completed homework. We deemed Wei and Dennis' profiles as being in very early stages of development, having not yet found solid footing.

Connecting Experience to Philosophy

In understanding how experience played a role in each participant's philosophy, it was clear that previous instructors in mathematics and statistics played an important role for all. For example, Sahil linked his preferred teaching style of covering fewer topics in depth through engaging lectures as exemplifying the professors he enjoyed most in his studies: "The interesting professors…were more into talking about intricacies of the theories, like for an example, why do we set a null hypothesis of a specific form. Why isn't the alternative hypothesis, the null and vice-versa...I've learned statistics in India, and I enjoyed it, so my idea is, students will probably also enjoy that thing." Kathy's philosophy was also connected to her experiences as a student, specifically her poor experiences with professors who she perceived as unapproachable: "For the majority, it was just kinda of lecturing, and actually my stats professor for the class I took junior year was not great…one time I went…and asked him a question, and he was like 'how do you not know this? Do you even go to class?'" As a result, Kathy envisioned a classroom that countered this experience and instead valued group work and in-class practice.

It was also clear that range of experiences related to statistics was a factor in each TA's philosophy development. Brad remarked that working as a lecturer and adapting the instructional materials provided by the on-sabbatical professor greatly influenced the depth of his classroom vision, and working as a data analyst enriched his understanding of what non-majors need and do not need from an introductory course. Other TAs limited exposure to statistics outside of a mathematics department seemed to influence the depth of their philosophies, although many of these TAs (e.g., Li, Kathy, Mindy) were explicitly aware of this limitation. Thus, these TAs' philosophies were framed within the paradigm that statistics is fundamentally applied mathematics.

CONCLUSION

Many statistics departments place considerable responsibility on TAs to adequately prepare undergraduate students for a world of data. Therefore, it is necessary that TAs have access to high-quality preparation that builds on their existing ideas and philosophies. Superficial training that simply tells TAs to "promote more active learning" may not be thoroughly taken up and understood by those who had positive experiences with professors who predominately lectured. Preparing TAs effectively should involve integrating research-based practices with their own experiences and beliefs to create a robust vision for teaching statistics. Additionally, we cannot assume that TAs entering a graduate statistics program conceive of statistics as a discipline with its own unique identity; attention may be needed to facilitate a deeper disciplinary understanding.

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