CHARACTERIZING IMPACTS OF ONLINE PROFESSIONAL DEVELOPMENT ON TEACHERS' BELIEFS AND PERSPECTIVES ABOUT TEACHING STATISTICS

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With online learning becoming a more viable option for teachers to develop their expertise, our report shares one such effort focused on improving the teaching of statistics. We share design principles and learning opportunities, as well as discuss specific impacts evident in classroom teachers' course activity concerning changes to their beliefs and perspectives about statistics. Specific course experiences that served as triggers for critical reflection are discussed.

Keywords: Teacher Education-Inservice/Professional Development, Teacher Beliefs

Statistics has gained a prominent place in middle and high school curricula through the National Council of Teachers of Mathematics (2000), Common Core State Standards (National Governors Association Center for Best Practice & Council of Chief State School Officers, 2010), and recommendations endorsed by the American Statistical Association (Franklin et al., 2007; Franklin et al., 2015). Professional development (PD) for secondary teachers to develop their statistical content and pedagogy are being offered across the country, typically on a small local scale, and these often include focused evaluation and research efforts to document impacts. However, the need for preparing teachers to teach statistics is much bigger than what can be addressed with small local programs. In this paper, we discuss a way of leveraging the internet to assist in a solution that is free, open access, and can reach many more teachers across geographic boundaries (Kim, 2014). With an online solution at a much larger scale, methods for examining impacts must also evolve. We offer a glimpse at one effort to use course participants' online activity, forum discussions, and self-reported changes on surveys as a way to measure impact.

For a "massive" and "open" course, there are many design challenges to meet the needs of participants with varied backgrounds. Massive Open Online Courses (MOOCs) are designed and delivered in a variety of ways, depending on learning goals for participants, to serve different target populations and provide diverse experiences for learners. In recognizing the potential for MOOCs to serve as large-scale PD, some are crossing local boundaries to design MOOCs specifically for Educators (MOOC-Eds, Kleiman, Wolf, & Frye, 2014). Those that engage in and study impacts of professional development for mathematics and statistics teachers must consider how this new frontier can potentially assist in developing teachers' content understanding and pedagogical strategies for improving practice, and forming global communities of educators. To contribute to the synergistic discussion needed at this crossroad, our focused question for this report is:

> *How can the experiences in an online professional development impact participants' perspectives about the nature of statistics and teaching statistics? Which resources and experiences in the course seem to influence any changes in perspectives?*

Literature and Framework

Beliefs and perspectives about statistics include a teacher's ideas about the nature of statistics, about oneself as a learner of statistics, and about the classroom context and goals for students' learning statistics (Gal, Ginsburg, & Schau, 1997; Pierce & Chick, 2011; Eichler, 2011). Certain beliefs would likely lead to different teaching practices. For example, if a teacher believes that statistics is a way of quantifying data and that the many procedures available in statistics for computing measures lead to such quantification, his or her teaching practices may favor a focus on

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statistical procedures and have less emphasis on the context of the data, the process of ensuring good data is collected and available (sampling methods), and making claims about data that are uncertain in nature (Pierce & Chick, 2011). Eichler (2011) further discusses how the focus of teachers' intended curriculum in statistics can be considered on a continuum from traditionalists (focused on procedures absent of context), to those wanting students to be prepared to use statistics in everyday life (focused on engaging in an investigative process that is tightly connected to contexts of real data). A goal in statistics teacher PD is to move teachers along this continuum towards a focus on investigative processes, which requires impacting teachers' beliefs about the nature of statistics and learning goals for students related to statistics.

Professional development that includes accessible, personalized, and self-directed elements can provide increased opportunities for sustained, collaborative and meaningful work among teachers that can affect their knowledge, beliefs and practice (e.g., Vrasidas & Zembylas, 2004). Researchers have found that online professional development (OPD) that addresses the varied needs and abilities of its participants can be effective in changing teachers' instructional practice (e.g., Renninger et al., 2011; Yang & Liu, 2004). Designers of OPD should be especially mindful that activities are meaningful, accessible and relevant so that participants can apply their learning to their educational context (Ginsburg, Gray, & Levin, 2004; Vrasidas & Zembylas, 2004).

Just as communities of practice can exist in face-to-face PD, OPD should facilitate development of an online community of practice (CoP). Researchers have highlighted benefits of such communities that are not always afforded in traditional face-to-face PD. For example, Mackey and Evans (2011) argued that online CoPs provide members with "extended access to resources and expertise beyond the immediate school environment" (p. 11), thereby offering ongoing PD and the potential for increased application in their classroom. Designers of OPD should build infrastructure to support such communities across geographic and time zone boundaries. Asynchronous discussion forums, for example, provide opportunities for participants to reflect on practice, exchange ideas, and discuss ways to improve on their own schedules with colleagues with whom they may not otherwise interact (Treacy, Kleiman, & Peterson, 2002).

While making changes in teachers' statistics teaching practices and ultimately changing students' learning of statistics is a major goal, we are guided by the integrated model for PD proposed by Clark and Hollingsworth (2002). In this model, they represent the change process for teachers through PD as being one that includes reflection and enactment among an external domain and a teacher's professional world that includes domains of personal, practice, and consequence. The external domain includes information and resources often experienced through a PD, including interactions with others. In our study the external domain includes the resources in the OPD and the discussions with others in forums. The personal domain includes one's knowledge beliefs and attitudes. The practice domain includes any professional experimentation, with content or instructional strategies, and the domain of consequence is concerned with salient outcomes that result in practice. Because of the massive size of our OPD about teaching statistics, we are most concerned with the reflections and enactments between the external domain (experiences and resources in the OPD) and the reflections and enactments we can discern concerning their beliefs and perspectives about statistics and teaching statistics. Though some teachers may be able to engage in professional experimentation during the course, this is hard to examine given everyone's different curriculum and timing of when statistics units may be taught. To aid us in considering how PD experiences may have an impact on teachers' beliefs and perspectives related to statistics, we draw upon Mezirow's (2009) theory of transformational learning in adult education. Specifically, we are interested in what stimulus in the OPD (external domain) may act as triggers to evoke dilemmas (or cognitive dissonance) for teachers where they question their understandings or perspectives that have been formed from prior experiences.

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Online Professional Development Context

The MOOC-Ed effort at the Friday Institute for Educational Innovation includes several courses built using research-based design principles of effective PD and online learning (Kleiman, Wolf, & Frye, 2014) that emphasize: (a) self-directed learning, (b) peer-supported learning, (c) job-connected learning, and (d) learning from multiple voices. One such course, *Teaching Statistics Through Data Investigations* [TSDI], aimed to have participants think about statistics teaching and learning in ways likely different from their current practices and past experiences. The course did not focus on a particular grade band or specific statistical content. A major goal was for teachers to consider statistics as an investigative process, promote statistical habits of mind, and view learning statistics from a developmental perspective.

The TSDI course consisted of an orientation unit and five units (http://friday.institute/tsdi). The course was open for about 15 weeks to allow for flexibility for participants to engage while managing their busy professional lives. Units began with an Introduction video of the instructor highlighting critical aspects of teaching and learning statistics in the unit. The Essentials included materials to read or watch. The design principle of learning from multiple voices guided the decision to include many videos of Expert Panel discussions with the instructor and three experts in statistics education. Multiple voices were also present in many classroom videos with teachers and students working on statistics tasks using various technology tools, as well as, animated illustrations of real students' work were created (using tools like Go Animate or Powtoon) that represented students' statistical reasoning and use of technology tools.

Self-directed and job-connected learning opportunities included Dive Into Data experiences in each unit for participants to use a variety of free technology tools (e.g., Gapminder, Tuva, CODAP, GeoGebra simulations) or import data into their own data analysis tool (e.g., Fathom, StatCrunch). These experiences allowed teachers to use tools accessible in their schools and connected them to relevant and free sources of data that can be useful in their lessons. For example, in Unit 4, the Dive Into Data used the Census at Schools website and asked teachers to download data and engage in statistical investigation. Extensions in each unit include extra resources (e.g., data sets, lesson plans, brief articles, java applets, additional videos) and provide self-directed opportunities to explore resources that may be useful in their educational context.

Peer-supported learning is a cornerstone of the MOOC-Ed experience. Since participants are geographically dispersed, it is important to provide focused and ample opportunities for them to connect with and support one another in learning and applying the material in the course. Each unit contains two discussion forums: 1) a forum focused on discussing a specific pedagogical investigation about aspects of teaching statistics (e.g., analyzing statistics tasks, considering students' approaches to statistics tasks through video clips), and 2) a forum where participants start their own discussions about unit materials or other ideas related to teaching statistics.

Building upon an existing framework (GAISE, Franklin et al., 2007), the development team incorporated recent research on students' statistical thinking and productive statistical habits of mind into a new framework, Students' Approaches to Statistical Investigations [SASI]. There were several learning opportunities for participants to develop an understanding of its importance and potential ways it can influence teaching. The diagram in Figure 1 shows the investigative cycle, reasoning in each phase can occur at three levels of sophistication, and productive habits of mind. Two brief PDF documents described statistical habits of mind and the framework. In a video, the instructor illustrated the framework using student work from research, and another video featured an expert illustrating development of the concept of mean across three levels. Participants could watch two animated illustrations of students' approaches to an investigation using different levels of statistical sophistication and then discuss students' work. More details about the design of the TSDI course can be read in Lee and Stangl (2015).

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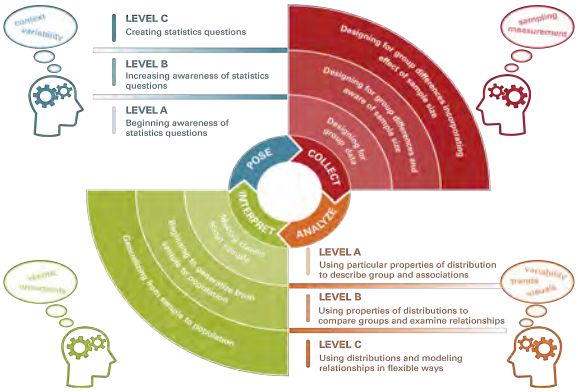

Figure 1. Framework for supporting students' approaches to statistical investigations.

Methods

Participants

Though the course is offered several times per year, we focus here on Fall 2015, the second run of the course. The course was advertised through many different organizations (NCTM, ASA, CAUSEweb), social media posts, state-level leaders in mathematics education, and personal contacts. Enrollment was free and open. For the purpose of this paper, we are only interested in how course experiences could be impacting beliefs and perspectives of K-12 classroom teachers. From registration (n=827), we discerned demographic characteristics and focused on those participants self-classified as classroom teachers (n=489). The classroom teachers resided in 46 states and 29 countries, with majority in the US (n=380) and New Zealand (n=48). The majority were female (67.5%) and 72.8% had a master's degree or above. Their years of experience in education were evenly distributed, creating a diverse community with varied teaching experiences that impact their starting perspectives and growth opportunities. Of those 489 self-identified classroom teachers, we confirmed 412 were actively working in K-12 contexts (e.g., some classified themselves as classroom teachers but taught community college).

Data Sources and Analysis Methods

Aside from registration data, four other data sources were used. Course activity was tracked through click logs that allowed us to examine trends in participants' engagement with material. Qualitative data was collected from three sources: 1) posts in discussion forums (two per unit, for a total of 10 forums), 2) open-ended responses to end-of-unit and end-of-course surveys, and 3) a follow-up survey sent 6 months after the course to inquire about how participants may have applied their learning and what they considered the most impactful ideas from the course.

All registration and click log data was merged and displayed in a dashboard in Tableau that allowed investigators to visualize participants' engagement over time and with certain types of resources. The dashboard facilitated the ability to filter by role of classroom teacher, so that we could examine and report on trends of the 489 participants classified as classroom teachers. Descriptive statistics and graphical displays were used to examine engagement patterns. All discussion forum log data was filtered to only include posts from those classified as classroom teachers. Because our research question was focused on how K-12 classroom teachers' beliefs and perspectives may be impacted by course experiences, it was important to maintain information about which activity and unit the discussion forum was embedded in, but not information about all posts from all participants. For the results reported in this paper, we are not discussing the impacts of particular ideas posted by participants or the social networks that formed in the forums as an indication of a community of

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practice (this is part of a larger study). The 977 discussion forum posts were analyzed using open coding guided by our focus on change in beliefs and perspectives related to teaching statistics. Each post was considered a unit of analysis and we were specifically coding instances where teachers self-reported changes or shifts in their beliefs and perspectives. The coded posts were sorted until four themes emerged. Within the themes, the posts were re-examined and tagged for evidence of what seemed to be triggering the change in perspective. We documented which triggers were most prevalent and only kept triggers associated with many instances of impacts on perspectives and beliefs, and discarded those only occurring once or twice. These themes and triggers were then used to examine responses on the end-of-units, end-of-course, and follow-up surveys. While we were looking for confirming and disconfirming evidence of themes and triggers, disconfirming evidence was not evident and no new themes or triggers were documented.

Results

Engagement

When registration opened, participants could enroll and engage in the Orientation unit that included an overview video, survey to self-assess their confidence in teaching confidence, and an introduction forum. Each unit opened in weekly intervals for 5 weeks, with earlier units always accessible when later units opened. This allowed for participants to start and engage in course material on their own time and pace, which is part of the self-directed design principle. Once Unit 5 opened, the entire course remained active for seven more weeks. After the course closed, participants could still access course material and read discussion forums in a read-only format (no new posts allowed in forums). In this way, the course site remained an open resource.

Overall, a majority (n=370) of enrolled classroom teachers engaged in various aspects of the course. Thus, we use 370 as the number of classroom teachers who began the course. With respect to accessing the course by units, the greatest number of classroom teachers accessed Unit 1 followed by Unit 2. In Unit 1, 293 classroom teachers engaged, but by Unit 5, only about 25% (n=92) of the classroom teachers that began the course had accessed material. The number of classroom teachers accessing the course in Units 3-5 was relatively the same, indicating that most classroom teachers who engaged through Unit 3 finished the course in its entirety.

The most accessed resources were discussion forums and videos (instructor videos, expert panel, and classroom and student work videos). 206 of the classroom teachers who began the course (56%) posted to a forum. The frequency of posts per teacher who engaged in forums is a skewed distribution (Figure 2), with 57% of teachers posting 1-3 times (typically in Units 1-2), 38% posting 4-14 times across several units, and 11 very active teachers posting 15-45 times. The levels of engagement in discussion forums and videos were highest in Units 1 through 3. Teachers' highest level of engagement with videos was in Unit 3 where 93 teachers took advantage of the video-based learning opportunities related to the SASI framework.

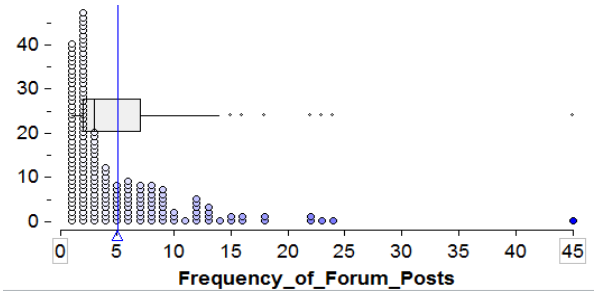

Figure 2. Frequency of posts per teacher across all discussion forums.

Impact on Perspectives and Beliefs

Looking carefully at themes from our coding, we saw four major ideas emerge related to how teachers' beliefs and perspectives may have changed:

1. engaging in statistics is more than computations and procedures and should include investigative cycles and habits of mind;
2. engaging in statistics is enhanced by the use of dynamic technology;
3. engaging in statistics requires real (and messy) data; and,
4. statistical thinking develops along a continuum.

Due to space limitations, we only elaborate on the first and last with examples from teachers.

We noticed a shift begin in Unit 1 with participants thinking about statistics as *more than computations and procedures*. This was expanded by posts in later units and evident in the survey responses. There were two aspects to this shift in perspective. The first seemed to be a realization that the statistics they experienced and that they tend to teach was too focused on procedures, and that this focus was not aligned with what they were experiencing in TSDI. For example, a teacher started a discussion thread detailing a dilemma because of points made in a video by statistics education experts in Unit 2. The extensive post began as:

> I had a "lightbulb moment". Although I have been teaching HS math for 24 years, I have never actually taught "statistics" as defined by the members of the expert panel. I have taught units that I THOUGHT were statistics, but I was merely providing students with a few mathematical tools that statisiticians [sic] can use (e.g. finding a mean, making a histogram, calculating a standard deviation, etc.)...(female, 24 yrs experience)

Twelve participants joined that discussion, 10 of which were teachers. They echoed that they were "guilty" of teaching statistics this way and that their own prior experiences in learning statistics treated the subject in a procedural manner. Similar discussions and replies about this issue were also started by several others. Teachers also recognized that attending and engaging in all parts of an investigation would give students opportunities to make sense of how statistics is used to answer questions and how important data collection (or experimental design) is to the process. Many admitted they spent little time on this with students and aimed to improve.

Related to the final idea that emerged, teachers seemed to realize that statistical thinking and understanding develops across a continuum and that they can use this to think about instructional decisions and assessment of students. "The idea of the 4 process cycle and the different levels for different ages of each process, has helped me lot. I understand more and feel I am a better teacher to my students" (female, 15 yrs experience). Considering statistics as developing across levels seemed to impact many teachers. For example, after commenting on students' work in a video and describing what levels she thought students may be working at, a teacher (10 yrs experience) noted, "with the SASI framework, I like how it never mentions age or grade level. I feel it's a continuum that students, depending on the context, can move back and forth between. If they get to a harder problem, they may not know how to exactly collect the data without bias and ensuring randomness. But with an easier experiment, that may be more obvious to them."

Triggers for Dilemmas

Four elements emerged as often cited for triggering critical reflection that had impacts on beliefs and perspectives about statistics and teaching statistics. By far, the *SASI framework* (and associated documents and multimedia) was the most dominant trigger for change. The *expert panel video discussions* and the *videos of students and teachers* engaged in statistics tasks were also dominate triggers to assist teachers in reconsidering their prior experiences in learning and teaching statistics,

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and help them envision a different outcome for their students if they change their practices. The *use of technology for visualizing data with real data* that are multivariable and "messy" was an additional trigger that seemed to impact perspectives. The technology experiences directly influenced their ideas that engaging in statistics is enhanced by using dynamic technology tools and real world messy data. These triggers came from learning opportunities that included videos of students and teachers engaged with messy data using technology, discussions in expert panel videos, and opportunities to Dive into Data. Two frequently referenced experiences were using the Gapminder tool, and engaging with Census at School. When asked the most valuable thing they learned on a follow-up survey, a teacher responded as follows, with triggers bolded that may have sparked her learning.

> "The most valuable aspect of the MOOC was obtaining **resources for the improved use of technology** to make instruction come to life and be more meaningful to students. I was able to **see the statistical process in action** and now have an idea of **what it should look like in the classroom**." (female, 19 yrs experience)

Discussion

One of the challenges in designing OPD for teachers is identifying how to leverage stimuli that has the potential to act as triggers to impact teachers' beliefs about teaching. For those who are at a crossroads facing this challenge, whether face-to-face or online, our identification of triggers can provide guidance as they embark on PD efforts for teachers. While we have no evidence (yet) that teachers experiences in a brief OPD in teaching statistics has impacted actual teaching practices and students' learning, our research indicates that the purposeful design elements of the course were successful in causing critical reflection through certain triggers. Many teachers appear to have moved along the continuum described by Eicher (2011) towards beliefs that we should engage students in doing statistics through investigations, not merely teach them mathematical tools to apply to numbers devoid of context.

Teachers are attracted to and can make sense of how frameworks apply to their practice and within the context of their learning environments. In addition, they learn a lot from expert opinions (beyond just a single PD instructor), as well as from the voices and experiences of other teachers with whom they collaborate with as part of the course. These voices act as additional resources outside of their physical school environment (Mackey & Evans, 2011) to impact their perspectives about statistics and teaching statistics. In accordance with other researchers, the discussion forums indeed provided opportunities for critical reflection about teaching statistics.

Teachers also learn a lot about what it means to engage in statistics, by doing it, as well as from examining students' thinking. Is any of this a big surprise? Perhaps not to experienced teacher educators. However, the key is to include these types of learning opportunities and potential triggers in professional development that occurs online, whether it is to a local group or massive and open to teachers around the world. Our research also supports the idea that online professional development that emphasizes: (a) self-directed learning, (b) peer-supported learning, (c) job-connected learning, and (d) learning from multiple voices can be effective for areas in mathematics education (e.g., teaching statistics) that need wide-scale efforts.

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