Jl. of Technology and Teacher Education (2019) **27**(2), 129-163

Participating in a MOOC and Professional Learning Team: How a Blended Approach to Professional Development Makes a Difference

KEMAL AKOGLU, HOLLYLYNNE S. LEE, SHAUN KELLOGG
North Carolina State University, USA
kakoglu@ncsu.edu
hstohl@ncsu.edu
sbkellog@ncsu.edu

Massive open online course *for educators* (MOOC-Ed) provide opportunities for using research-based learning and teaching practices, along with new technological tools and facilitation approaches for delivering quality online professional development. The *Teaching Statistics Through Data Investigations* MOOC-Ed was built for preparing teachers in pedagogy for teaching statistics, and it has been offered to participants from around the world. During 2016-2017, professional learning teams (PLTs) were formed from a subset of MOOC-Ed participants. These teams met several times to share and discuss their learning and experiences. This study focused on examining the ways that a blended approach to professional development may result in similar or different patterns of engagement to those who only participate in a large-scale online course. Results show the benefits of a blended learning environment for retention, engagement with course materials, and connectedness within the online community of learners in an online professional development on teaching statistics. The findings suggest the use of self-forming autonomous PLTs for supporting a deeper and more comprehensive experience with self-directed online professional developments such as MOOCs. Other online professional development courses, such as MOOCs, may benefit from purposely suggesting and advertising, and perhaps facilitating, the formation of small face-to-face or virtual PLTs who commit to engage in learning together.

INTRODUCTION

Many researchers consider professional development (PD) as the keystone for educational improvement (Hawley & Valli, 1999). However, face-to-face PD sometimes cannot fit easily into teachers' schedules, and resources are often not locally available. The premise of a massive open online course (MOOC) is that it is scaled to reach as many learners as possible across a dispersed geographic area, designed for flexibility in time for engagement, and bears little to no cost to a participant. When a MOOC contains material particular for training in a specific profession (e.g., nursing, teaching, counseling), it has a much more specific target audience and can be a form of professional development (PD) in an online setting. For K-12 and college teachers, the availability and affordability of MOOCs has created possibilities to seek and engage in learning opportunities of interest to them. Early efforts showed that teachers were indeed interested and engaged in MOOCs containing content not designed or intended specifically for teachers (e.g., Seaton, Coleman, Daries, & Chuang, 2015). MOOCs designed specifically for K-12 teachers can provide positive self-directed learning experiences and rich engagement in discussion forums that help form online communities for educators (e.g., Ferdig, Pytash, Merchant, & Nigh, 2014; Kleiman & Wolf, 2015). Specifically, for teachers of mathematics and statistics, recent efforts have included designing and offering online PD in MOOCs (e.g., Anderson, Boaler, & Diekmann, 2018; Avineri, Lee, Tran, Lovett, & Gibson, 2018; Borba et al., 2016; Lee & Stangl, 2017).

For the past two decades, attention to statistics has increased in secondary curricula in the U.S. through efforts by 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). However, many teachers struggle with teaching statistics and often lack the experience, understandings, and confidence in statistics to meet the demands of the curriculum (e.g., Burgess, 2011; Harrell-Williams, Sorto, Pierce, Lesser, & Murphy, 2015; Leavy, Hannigan, & Fitzmaurice, 2013; Lovett & Lee, 2017a, 2018). While local face-to-face PD efforts in statistics and statistics teaching can have impacts on teachers' learning and practices (e.g., Friel & Bright, 1998; Makar & Fielding-Wells, 2011), the need to prepare teachers to teach statistics is much bigger than what small local professional development (PD) efforts can accomplish alone.

A NEW IDEA FOR BLENDED PROFESSIONAL DEVELOPMENT

Many professional development projects over the past 20 years have used a blended or hybrid model that includes some combination of online and face-to-face components (Lantz-Andersson, Lundin, & Selwyn, 2018). Some studies examine such a blended approach where participants are in a group that experience the online and face-to-face components as a cohort (Luebeck et al., 2017), and others where the online component includes a much broader set of participants in a MOOC with a smaller group that experiences a face-to-face component parallel to the online course (e.g., Anderson, Boaler, & Diekman, 2018; Hasser, 2017).

Our study offers a new perspective on research concerning the use of a blended approach to professional development. In this study, blended professional development refers to a model that combines a large online course with locally formed professional learning teams that are dispersed across the U.S. The intent was to support and examine the impacts of a blended approach to professional development that included several autonomous small groups of educators who met 5-7 times on their own schedule and simultaneously participated in an online course to engage with materials and have the opportunity to participate in the larger online community of participants through discussion forums.

The professional development online course in our study is open and accessible to any educator who desires to improve their practices related to teaching statistics. The course is part of a series of MOOCs for educators (MOOC-Eds) developed at the Friday Institute for Educational Innovation at NC State University. The members of the smaller groups were self-organizing and led by one of their own members, rather than an instructional leader associated with the MOOC-Ed. These small group professional learning teams (PLTs) had informal structures, operating autonomously from one another and could set their own timelines and agendas related to the course and how they wanted to make local changes to their teaching practices. Those who chose to join the PLTs were only a small subset of those engaging in the MOOC-Ed.

In this paper, we are not examining the impact of the blended PD on changes in the teachers' perspectives and approaches to teaching statistics; see Akoglu (2018) for details on this larger study. Instead, we are interested in unpacking how participants who enroll in an online course for the purpose of professional development may benefit from also being in a smaller group of professionals committed to engaging in the same PD. Thus, our research is focused on examining the ways this type of blended approach

to professional development may result in similar or different patterns of engagement to those who only participate in the MOOC-Ed. Our focused research question for this paper is: *What are the similarities and differences between how PLT members and Non-PLT online participants engage and meet course goals in a MOOC-Ed designed for educators in secondary and collegiate settings?*

LITERATURE REVIEW

Online Professional Development

According to Lock (2006), realizing the potential of online communities to facilitate teacher professional development requires a readiness to change the current perceptions about professional development. The design of the online PD, thus, should trigger that change. Therefore, an evolutionary path toward real-time, ongoing, work-embedded, research-based professional development has led to the creation of many online teacher professional development programs that can be used to improve teachers' understanding of learning and change their teaching practices (Dede, Ketelhut, Whitehouse, Breit, & McCloskey, 2009; Sprague, 2006). Indeed, Marrongelle, Sztajn and Smith (2013) proclaimed it was "incumbent on the field to capitalize on emerging technologies in the design and delivery of effective professional development" and emphasized the need for "research that focused on teacher learning in these environments" (p. 208).

Recommendations from the Conference Board of Mathematical Sciences (2012) purport that in professional development, teachers should engage where they solve mathematics tasks, deeply explore content in a professional learning community, analyze students' mathematical work, and participate in collaborative task design. Further, teacher PD that includes elements that are accessible, personalized, and self-directed can increase opportunities for collaborative and meaningful work among teachers that can affect their knowledge, beliefs and practice (e.g., Vrasidas & Zembylas, 2004). Online PD that is accessible, meaningful, and addresses participants' varied needs and abilities can be effective in changing teachers' instructional practice (e.g., Ferdig et al., 2014; Herrington, Herrington, Hoban, & Reid, 2009; Luebeck, Roscoe, Cobbs, Diemert, & Scott, 2017; Vrasidas & Zembylas, 2004). For example, in a study on the impact of online PD, Herrington et al. (2009) found that teachers succeeded in implementing new pedagogical strategies when they felt supported by their online community.

Several projects have combined online with face-to-face components in professional development for mathematics teachers. For example, Luebeck and colleagues (2017) engaged 60 middle school teachers across rural Montana in a sequence of experiences that began with coming together for face-to-face meetings then progressed to online modules and ended with face-to-face meetings. Anderson et al. (2018), studied the use of a highly structured blended PD model where a cohort of 40 teachers within 7 schools participated in an online course about mathematical mindsets and sustained local PD that included discussions of the online course materials, examining artifacts from teachers' classrooms, on-site coaching in their classroom and participation of administrators in the PD experience. In both studies, the blended approach to PD supported teachers' learning, changes in their teaching practices, and working together in a larger network of educators.

According to Kleiman, Wolfe, and Frye (2015), new approaches in online PD aimed at K-12 teachers and administrators are necessary "that embody the principles of effective PD and are scalable, accessible, and flexible to meet the needs of different educators" (p. 2). The authors call this a massive open online course *for educators* (MOOC-Ed), which provides opportunities for using research-based learning and teaching practices, along with new technological tools and facilitation approaches for delivering quality PD online. The MOOC-Ed efforts at the Friday Institute for Education Innovation have shown to provide effective PD for a wide audience of educators from geographically dispersed areas that create communities of educators online and enable participants to make changes in their instructional practices (Kellogg & Kleiman, 2018).

Communities of Practice to Support Teacher Learning

By forming or joining online teaching and learning communities, teachers can expand their circle of like-minded colleagues (Lieberman & Pointer Mace, 2008) through exchanging ideas and learning from geographically dispersed educators. An online (or virtual) community means "a group of people who regularly interact online and share common goals, ideals, or values" (Owston, 1998, p. 60). Avineri (2016) stated that the benefits of online communities are not always afforded in traditional face-to-face PD. For example, online communities of educators provide participants "extended access to resources and expertise beyond the immediate school environment" (Mackey & Evans, 2011, p. 11). Herrington, Reeves, and Oliver (2009) argued that educators achieved implementing new pedagogical strategies in

their practices when they receive the support of their online communities. Online PD programs should include ways for supporting these communities, because the members of online PD do not physically engage in activities together and are instead dispersed across time and geographical space.

Professional learning teams (PLTs) are often used as ways to organize and focus a group of practicing teachers on making changes to particular areas of their practice. Professional learning communities or teams (PLC or PLT) is a professional development model that has been used in the past 20 years that includes high levels of collaboration with a small group of teachers, often with a focus on student work and school-level data (DuFour, 2004). Those small groups provide opportunities for educators to share teaching practices, observe students' learning, and make plans for targeted changes to their classroom practices.

Both professional development mechanisms in this study (MOOC-Ed and PLT) fit a community of practices (CoP) framework. Wenger (2011) defines CoP as "people who engage in a process of collective learning in a shared domain of human endeavor: a tribe learning to survive, a band of artists seeking new forms of expression, a group of engineers working on similar problem" (p. 1). According to Wenger, a CoP has three main characteristics: the domain, the community, and the practice. The domain involvement in the community requires some knowledge and some competence in the domain. In the context of this study, the domain is teaching statistics through investigations. The community are members interacting and learning together in joint activities and discussions. In the context of our study, there are two community levels possible--a MOOC-Ed community, and a PLT community. Shared experiences (readings, videos, tasks) and forum discussions are part of the first level, and the PLT meetings and discussions form a second level community. The practice includes members of the community whom "develop a shared repertoire of resources: experiences, stories, tools, ways of addressing recurring problems--in short a shared practice" (Wenger, 2011, p. 2). In this study, the educational practice is a shared commitment to improving teaching of statistics.

THE BLENDED PROFESSIONAL DEVELOPMENT CONTEXT

MOOC-Ed Design

In 2015, Hollylynne Lee and her colleagues launched the *Teaching Statistics Through Data Investigations* [TSDI] MOOC-Ed to prepare teach-

ers in pedagogy for teaching statistics (see http://go.ncsu.edu/tsdi). The MOOC-Ed was part of a larger effort at the Friday Institute for Educational Innovation to create and implement MOOCs designed specifically for educators using design principles based on effective professional development (Kleiman, Wolfe & Frye, 2015). These design principles emphasize that online professional development should support: (a) self-directed learning, (b) peer-supported learning, (c) job-connected learning, and (d) learning from multiple voices.

The TSDI MOOC-Ed aims to have participants think about statistics teaching and learning in ways that are likely different from their current practices in middle school through college-level introductory statistics. A major goal is for educators to be introduced to and use a framework to consider statistics as an investigative process with four phases (pose, collect, analyze, interpret) that incorporates statistical habits of mind, and view learning statistics from a developmental perspective (Franklin et al., 2007). This view of teaching statistics is often not representative of the current practices in K-12 classrooms. The course consists of an orientation unit and five units, each with six components. The course opens for 12-15 weeks to allow for flexibility for participants to engage while managing their busy professional lives. Units begin with an introduction video where the instructor explains the unit structure and highlights critical aspects of teaching and learning statistics in the unit. In Fall 2016-Spring 2017, the semesters of focus for this study, the entire course opened all at once, with orientation and all units immediately available. Bi-weekly emails were sent to all MOOC-Ed participants to recap points made in discussion forums, and remind them of key content, requirements for a certificate of completion, and when the course would close.

The design principle of learning from multiple voices suggests that learning opportunities can be enriched by valuing the knowledge and perspectives of others, rather than having a sole instructional expert. Thus, each unit in the course includes a video of an Expert Panel discussion with the instructor and 3 experts in statistics education. Multiple voices were also present with the inclusion of many short (5-10 minute) classroom videos with teachers and students working on statistics tasks using various technology tools. However, when rich examples were available in statistics education literature, animated illustrations of real students' work were created (using tools like Go Animate or Powtoon) that represented teachers posing tasks and students' statistical reasoning and use of technology tools. These types of animated videos of mathematics classroom practices have been successfully used in many face-to-face and online mathematics teacher education

contexts (e.g., Herbst, Chazan, Chen, Chieu, & Weiss, 2011; Lovett & Lee, 2017b; Zazkis & Herbst, 2017). Such videos (real or animated) of classroom practice brought in the voices of those closest to daily educational practices and allow participants to envision possibilities in their classrooms.

Self-directed and job-connected learning opportunities include Dive Into Data experiences in each unit for participants to use a variety of free online technology tools (e.g., CODAP and TUVA) or import data into their favorite statistical tools. These experiences give teachers the choice to use tools accessible in their schools and connect them to relevant and free sources of data that can be useful in their lessons. Extensions in each unit include extra resources (e.g., data sets, lesson plans, brief articles, applets, additional videos) and provide opportunities to explore content and resources of interest to educators and useful in their educational context. A major way the course supports self-directed learning is that the flexibility for when participants can engage and how they decide to traverse the materials and choices they are allowed to make to access and utilize different resources and videos in the course.

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 material from the course. The orientation unit includes an opportunity for participants to introduce themselves in a discussion forum and reveal their choice of professional and personal aspects about themselves. Each of the five units 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. These discussion forums also brought in multiple voices of practicing educators where community members could learn with each other and discuss topics relevant to their practice. More examples about the design of the course are available in other articles (e.g., Lee & Stangl, 2015, 2017)

In an effort to support a blended approach to professional development, a 18-page facilitator's guide was created that gave suggestions for how to structure meetings and included discussion prompts related to specific material in each unit (http://fi-courses.s3.amazonaws.com/tsdi/PLCguide/tsdi_plc_guide.pdf). Several suggestions were also made in the guide for actions teachers could take in their classroom in between meetings or how they could bring artifacts from their own practice (e.g., lessons or tasks they

have used in the past, students' work on a task used in the course) into the team meetings. For example, Appendix A illustrates suggestions in the facilitator's guide for small group discussion related to course material in Unit 2. The facilitator's guide was described and accessible on the TSDI course home page so that all registered participants had access to this resource.

Small Group PLTs

While marketing materials for the course encouraged teachers to take the class with local colleagues, and indeed some reported in surveys they completed the course with local colleagues, a purposeful attempt was made in 2016-17 to assist and support teachers in forming small group professional learning teams of 3-7 colleagues (funded by a grant from the American Statistical Association). With a goal of supporting 10 PLTs, recruitment began for individuals who were interested in forming a local team and serving as a team leader. Announcements were sent to former TSDI MOOC-Ed participants who had completed most of the course (from Spring 2015, Fall 2015 and Spring 2016) and posted on a listserv that included educators who had an interest in teaching statistics. Potential leaders had 3 weeks to apply. The process and criteria to choose the leaders included the level of applicant's willingness to lead a team, and their background in statistics teaching. Those potential leaders were then asked to meet the initial requirement of forming a local professional team of 3-7 colleagues. The details of the PLT participants are included in the Methods section.

Each semester, before the course opened, the PLT leaders all met virtually in a video conference with the lead MOOC-Ed facilitator (Author 2) and a facilitator who would assist in managing the logistics of and supporting the PLTs (Author 1) to discuss ideas for supporting their own local teams. In this orientation for leaders, we discussed the Facilitator's guide and suggested that one possible format would be to schedule a meeting to discuss content in each unit. However, the leaders were free to work with their small group to schedule meetings and agendas that made the most sense for the goals of the group. We encouraged the leaders to engage in the MOOC-Ed as little or as much as they felt was needed to prepare themselves to lead the small group meetings. They were not given any specific instructions about how they should participate in online discussion forums but that they may want to at least sometimes look to see if their small group participants were raising any questions, concerns or ideas in the forums which may be important to include in PLT discussions. The PLT leaders

were also asked to complete a brief online survey after each meeting to provide a brief log and record of what occurred at each meeting. Upon completion of the blended PD experience, the PLT leaders were paid a $750 honorarium for their efforts.

A leader and members of a PLT decided together on their meeting schedule. Those meetings mostly lasted about 1-hour. Participants discussed the recent TSDI MOOC-Ed unit and reflected upon their experiences. Author 1 attended many PLT meetings as a non-participant observer and answered technical questions during the meeting and through email. Some of the PLTs held their meetings face-to-face, and other teams held meetings through online video conference to meet the needs of scheduling of the members. Face-to-face PLT meetings took place either at a school where PLT members worked at, or at a education/research center in their district. On the other hand, virtual meetings were conducted through ZOOM, allowing participants to join the meetings from their computer, tablets, or even their mobile phones. Leaders who held meetings through ZOOM recorded the meetings, hence participants had the opportunity to view the recorded meeting later if needed.

METHODS

According to Wiebe, Thompson, and Behrend (2015), MOOC research should begin with an assumption that "the aspirational goal and emerging implementation model for MOOCs is one of a free-choice educational space" (p. 252). According to the authors, MOOCs inspire various types of learners who come to learn with their motivations and purposes. Their experiences, their core ability, and their psychological dimensions could determine their purposes. Indeed, we assume that the TSDI MOOC-Ed attracts a variety of different educators with different motivations for learning and varied background experiences related to the course content of teaching statistics. Some may be long time statistics instructors at a college looking to pick up a few additional resources. Others may be middle or high school teachers looking for deep professional development to improve their statistics understanding and teaching strategies to meet the demands of new curricula standards. Thus, it is important to understand that MOOCs not only offer flexibility in engagement in time and space, but also provide access to learning opportunities where participants can choose which opportunities best fit their needs.

Participants

The TSDI MOOC-Ed course has been offered every semester since Spring 2015 to over 4000 registered educators from around the world (at least 84 countries). Recruitment for professional learning team (PLT) leaders occurred through email invitations to past course participants from Spring 2016 or earlier, as well as individuals with high interest in statistics education who were part of email listservs focused on statistics education.

For Fall 2016, 316 former active TSDI participants were contacted with an invitation email to apply to lead a PLT (i.e., all 2015 and 2016 Spring active participants were contacted). Twenty-two people completed the interest form indicating they wished to lead a team. The research team considered their responses and invited 11 people as potential PLT leaders. Those potential leaders were then asked to meet the initial requirement of forming a local professional team with at least 2 other colleagues who could commit to the blended PD experience (minimum of 3 in a PLT). Five leaders were successful in meeting this requirement, and thus five teams formed for fall 2016. Even though five PLTs were formed and planned to conduct at least five PLT meetings, one group was not able to get organized, and although the potential members of that group registered for the course, they did not participate in the MOOC-Ed or hold any PLT meetings. Thus, that team was eliminated, and four teams were successful in starting and completing the PLT project in Fall 2016.

As a different strategy, in Spring 2017, instead of contacting former TSDI participants, people who had an interest in teaching statistics were recruited through organizations such as the American Statistical Association (ASA) Statistics Education section and Consortium for the Advancement of Undergraduate Statistics Education (CAUSE) listserv. Six applicants were chosen as potential PLT leaders, and five of those formed a PLT. Four of those teams scheduled face-to-face meetings. One team was formed with members from different locations in the U.S. who had previously met each other through another professional development opportunity and scheduled virtual meetings.

The largest group in this study is all enrollees in the TSDI MOOC-Ed (n=804 total) from Fall 2016 and Spring 2017. There were 63 of these MOOC-Ed participants that also joined one of nine PLTs (see Figure 1). The way participants conducted their PLT meetings (virtually or face-to-face) is indicated in Figure 1 (dashed or solid line, respectively). Yellow PLTs were Fall 2016 participants, and green ones were Spring 2017 participants.

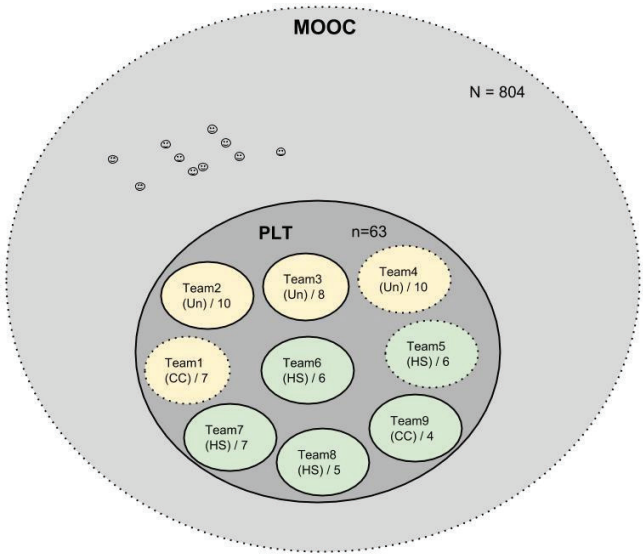

Figure 1. Participants in study (Un=university, CC=community college, HS=high school).

PLT leaders and members participated in the blended professional development project, while non-PLT MOOC-Ed participants engaged only in the online course, though some may have been taking the course with a local colleague that was unknown to the research team.

Data Sources

Our research is focused on similarities and differences in the engagement and outcomes of the PLT and non-PLT groups in the MOOC-Ed. The data sources included: pre and post Self-Efficacy for Teaching Statistics (SETS) survey (44 Likert scale questions, and 1 open-ended question), Unit Feedback surveys and End of Course survey (both Likert scale and open-ended questions), participants' online course activities (data logs for all MOOC-Ed participants viewed through a *dashboard),* discussion forum participation, and summary reports from PLT leaders about their meetings.

The Self-Efficacy for Teaching Statistics Survey (SETS; Harrell-Williams, Lovett, Lee, Pierce, Lesser, & Sorto, 2019) is designed to evaluate

participants' confidence about teaching various aspects of statistics. For 44 different topics, participants rate their confidence in teaching students the skills necessary to successfully complete the task on the following scale: 1-not at all confident; 2-only a little confident; 3-somewhat confident; 4-confident; 5-very confident; 6-completely confident. Structural, substantive, and content validity evidence for the scores from the SETS instrument have been validated (Harrell-Williams et al., 2019). Within the online course, the SETS surveys are offered as learning opportunities to participants twice-- in the Orientation unit (pre-SETS) to help them self-assess their confidence and set goals for their learning in the MOOC-Ed, and again available in Unit 5 (post-SETS) to self-assess and reflect on their growth and remaining challenges. There is one open-ended question on the survey for participants to elaborate on factors that affect their confidence. In Unit 5, they are specifically asked to discuss any changes in their confidence in discussion forums. Thus, the SETS survey results can help describe the growth in participants' confidence about teaching statistics.

Unit and end-of-course surveys in the MOOC-Ed are offered after each unit they finish, with Unit 5 survey having different summative questions than those in Units 1-4. The surveys include both open-ended and Likert-scale questions. The surveys intend to get information about what participants think of the units and the course, how comfortable they feel, and how much they think they learned related to their practice. These surveys are opportunities for participants to self-assess their experience as well as evaluate the course.

Course data logs were merged from several different data sources and displayed in a *Tableau* dashboard to visually depict course activity trends to allow us to visualize participants' engagement over time and with certain types of resources. The dashboard was updated daily and had the capability to filter participants by whether they were a PLT member or non-PLT member, so that it was possible to examine, compare, and contrast the activities of PLT and non-PLT participants. The following images illustrate some aspects of the Tableau dashboard (Figure 2).

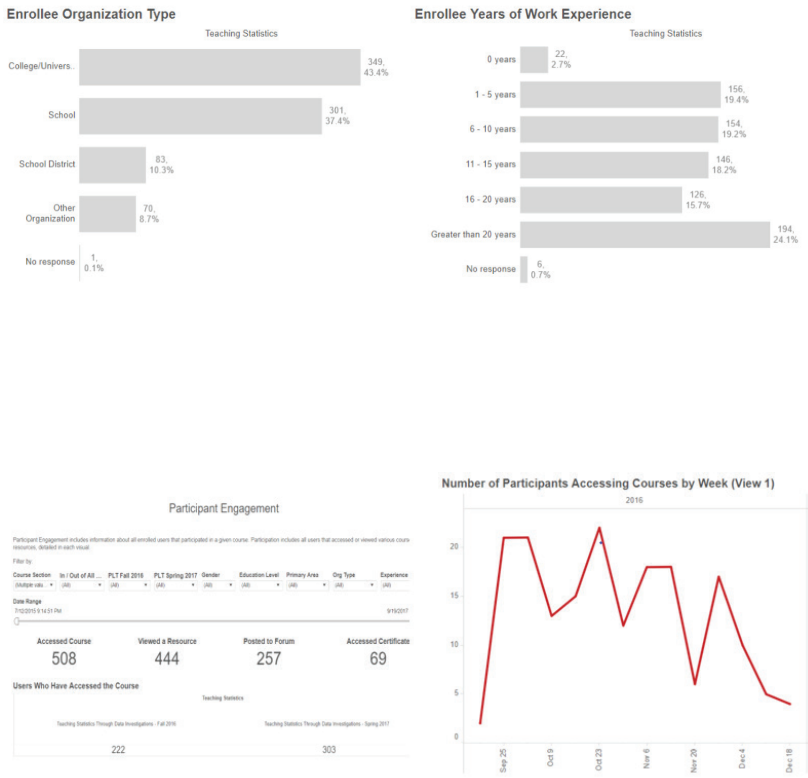

Figure 2. Images of Tableau dashboard created for TSDI MOOC-Ed.

Discussion forum participation was examined using descriptive statistics as well as social network analysis (SNA). SNA is a research methodology that seeks to identify underlying patterns of social relations based on the way actors are connected with each other (Scott, 2000; Wasserman & Faust, 1994), and can give a sense of the strength of the online community and how different groups of participants may be situated as actors in that community. It is common among large online communities to see a core-periphery structure (Wenger, McDermott, & Snyder, 2002; Newman & Park, 2003), in which most actors have few ties while a small number have many ties to other participants through discussion interactions.

ANALYSIS AND RESULTS

Who was attracted to the MOOC-Ed and joining a PLT?

Both the MOOC-Ed and PLTs represent communities of practice (CoP). As described earlier, a community of practice is a group of people gathered with a shared interest in a domain and engaged in a collective learning process (Wenger, 2011). In this study context, the MOOC-Ed and PLTs have a shared domain, and that is teaching statistics. The MOOC-Ed is a much larger CoP with much more variability in participants' educational practices than the practices of those in a local PLT. The PLTs include more practices that are shared by the members of a PLT; for example, PLT members actively and purposefully meet and discuss closely what they have recently learned in the course and make plans for implementing new resources and strategies in their classrooms. Table 1 presents the demographics of participants in the MOOC-Ed and the subgroup of those that were part of a PLT.

Table 1

Demographics of TSDI MOOC-Ed and PLT participants in 2016-2017

	All MOOC-Ed enrollees (N=804)	**Subset of PLT members (N=63)**
Gender	63% female (n=503) 35% male (n=281)	75% female (n=48) 24% male (n=15)
Geographic Location	80% in the U.S. (n=633)	100% in the U.S., across 7 states (n=63)
Primary focus of enrollee employment	62% classroom teaching (any level) (n=498)	76% classroom teaching (any level) (n=48)
Highest level degree in education	55% Masters (n=442) 24% PhD (n=193)	51% Masters (n=32) 25% PhD (n=16)
Organization type	43% College/University (n=346) 37% Middle/High School (n=297)	60% College/University (n=38) 30% Middle/High School (n=19)
Years of education experience	12 years (average)	14 years (average)

The enrollees in the MOOC-Ed consisted of 356 participants in fall 2016 and 489 in spring 2017. As seen in Table 1, the vast majority were from the U.S. and the rest were from other countries, with the majority be-

ing female. Overall, the majority of the enrollees indicated that their primary focus area of employment was classroom teaching (K-12 or college). The participants in the MOOC-Ed, including the subset of PLT participants were generally highly educated. Participants' years of experience in teaching varied, but both groups had an average of over 10 years of teaching experience.

In total, 63 PLT participants were registered for the MOOC-Ed during fall 2016 (n=37) and spring 2017 (n=29). Three participants enrolled in both semester's courses. As seen in Table 1, all PLT participants were from the U.S., with the majority being female (75%). Overall, 76% of the PLT members indicated that their primary focus of enrollee employment was classroom teaching (K-12 or college), where 6% chose curriculum and instruction; 6% were students (college and graduate school); and 6% chose teacher preparation. The PLT participants generally were highly educated, with 51% having a master's degree and 25% a PhD. Enrollees' organization type varied with most located in a college/university (60%), or middle or high school (30%). PLT participants' years of experience in teaching also varied. 25% of them had 20 years of experience or more; 18% of participants had 6-10 years of experience; 24% of participants had 1-5 years of experience; 14% of participants had 11-15 years of experience; 13% of participants had 1-20 years of experience; and the remaining 5% had no teaching experience.

Participant engagement

Among all non-PLT MOOC-Ed registered educators (n=741), only 60.5% of them actually accessed the course. As seen in Table 2, 40% of the non-PLT participants posted at least once to forum discussion (including the Introduction forum in the Orientation Unit), and 11% of them earned a certificate of completion. Earning a certificate was different from completing the course, though. Completing the course could be defined as accessing materials through Unit 5; with this, 17% of the non-PLT participants completed the course.

The participation rates were much higher in all categories for PLT members. Of the 63 PLT members registered for the course, 61 participants (97%) accessed the course, meaning two participants dropped out of the experience before ever engaging in the course, though they did attend at least one PLT meeting. As seen in Table 2, 84% of PLT members participated in forums, and 38% of them earned a completion certificate. The engagement across all five units was also remarkably higher for PLT members, with 70% completing the course through Unit 5.

Table 2
TSDI MOOC-Ed activity of participants in 2016-2017

	All MOOC-Ed Participants (N=804)	Non-PLT participants (N_1= 741)	PLT Members (N_2=63)
Accessed the course and viewed at least one resource	63% (*n*= 509)	60.5% (n_1= 448)	97% (n_2= 61)
Participated in forum (out of n, n_1 or n_2)	50% (255)	40% (179)	84% (51)
Average number of forum posts (out of n, n_1 or n_2)	6.82	5.81	10.84
Met requirements for a certificate of completion (access all units, participate in forums, take end of course survey) (out of n, n_1 or n_2)	14% (71)	11% (49)	38% (23)
Of those that accessed course, how many completed the course by engaging in materials in all 5 units (out of n, n_1 or n_2)	23% (117)	17% (76)	70% (43)

Being a PLT member required participants to attend 5-7 scheduled PLT meetings throughout their MOOC-Ed experience, though many team leaders reported less than total attendance at some meetings. This requirement and structure of scheduled meetings can help explain why PLT members' completion rate in the online course was much higher than non-PLT members. Table 3 provides a summary of each PLT and the number of times they met.

Table 3
PLT team information

Team	Grade / # of participants	General Description
Team 1	Community College N=7	The team was led by a former MOOC-Ed participant who took the course in a prior semester. The team consisted of 7 community college teachers from two institutions. 6 members completed the process. 6 meetings were held virtually.
Team 2	University N=10	The team was led by a former MOOC-Ed participant who took the course in a prior semester. The team consisted of 10 university instructors from the same university. Meetings were held face-to-face.
Team 3	University N=8	The team was led by a former MOOC-Ed participant who took the course in a prior semester. The team consisted of 6 university instructors and one graduate student from the same institution. All members completed the process. 6 meetings were held face-to-face.
Team 4	University N=10	The team was led by a former MOOC-Ed participant who took the course in a prior semester. The team consisted of 8 graduate students (preservice teachers) in an elementary math education department. 6 members completed the process. 6 meetings were held virtually.
Team 5	High School N=6	The team was led by a first time MOOC-Ed participant. The team consisted of 6 high school mathematics teachers. All members completed the process. The teachers met as part of a separate project about statistics education and teach in different districts and states. Five meetings were held virtually.
Team 6	High School N=6	The team was led by a first time MOOC-Ed participant. The team consisted of 5 high school mathematics teachers teaching at the same private school. All members completed the process. 5 meetings were held face-to-face.
Team 7	High School N=7	A former MOOC-Ed participant, who also led another university-based PLT the prior semester, led the team. The team consisted of 6 high school teachers teaching at different schools within the same district. 5 members completed the process. 5 meetings held face-to-face.
Team 8	High School N=5	The team was led by a first time MOOC-Ed participant. The team consisted of 5 high school teachers teaching at the same public school. 2 members completed the process. The 10 meetings were held face-to-face.
Team 9	Community College N=4	The team was led by a first time MOOC-Ed participant. At the beginning, the team consisted of 4 community college teachers at the same institution. Only two members completed the process. 5 meetings were held face-to-face.

A deeper dive into the online course activity of those participants who ever "showed up" to access the MOOC-Ed materials revealed stark differences between how PLT members and non-PLT MOOC-Ed participants engaged in the course (Table 4). While the distributions for both the number of days visited and the number of resources viewed are skewed right for the non-PLT and PLT group, there is a dramatic positive shift towards increased days visited and number of times resources were viewed for members in the PLT group. This provides strong evidence to say that PLT participants were richly engaged in the MOOC-Ed, and thus they had ample opportunity to learn from the online materials.

Table 4

Number of days the TSDI MOOC-Ed was visited, and resources viewed by participant type

	Non-PLT MOOC-Ed participants who accessed the course (n = 448)	**PLT participants who accessed the MOOC-Ed (n = 61)**
Number of days visited the MOOC-Ed	Mean=3.80; Median=2 (St.dev. = 3.41)	Mean=9.74; Median=9 (St.dev. = 8.11)
Number of times participant views resources (videos, readings, links to applets or lesson plans, etc.)	Mean=56.4; Median=16 (St.dev. = 52.24)	Mean=181.6; Median=159 (St.dev. = 166.24)

A core component in each unit of the course was the opportunity for participants to engage with one another in asynchronous discussions. TSDI has one introductory forum and 10 discussion forums (two in each unit). Even though the number of PLT participants that accessed the course (n=61) is around 1/9 of the total number of all course participants who accessed the course (N=509), many of the discussion forums included PLT participants' entries. Out of 628 total discussion threads in Fall 2016 and Spring 2017, there were 277 discussion threads including at least one PLT participant's entry, meaning that 44% of the discussion threads had contributions made by PLT participants. For example, a PLT member started a discussion thread titled as "New Ideas" in Unit 4 after an experience with a website using large messy data and watching videos of students' working with such data:

> "I have always wanted to incorporate some time of bigger project into my class but have feared greatly of what would happen. Often times I have students who struggle to understand simple arithmetic at the college level. I think this inspires me. Just gives them some data and let them go and see how they do with it." (Fall 2016, Unit 4)

The discussion in this thread continued with 4 other participants, 2 of which were also PLT members.

The average number of posts made by a PLT participant was 10.84, where the average number of posts made by non-PLT participant was 5.81. Thus, on average, every PLT participant has an entry for every forum discussion, and the average number of posts made by PLT participants is about double the average number of posts made by non-PLT online course participants.

We are very interested in how the MOOC-Ed afforded an opportunity for participants to be a part of an online community of professionals. In order to investigate engagement in forums beyond the Orientation unit (2 forums in each of 5 units), social network analysis (SNA) for one of the semesters (Fall 2016) was conducted. During Fall 2016 there were 4 PLTs who were engaged in the MOOC-Ed. We specifically used SNA to examine differences and similarities in how PLT members (n=31), PLT leaders (n=4), non-PLT participants (n=91), and the course facilitators (n=3) engaged with one another in discussion forums. The sociogram in Figure 3 illustrates the connections among PLT members (green square), PLT group leaders (white and green triangle), non-PLT online participants (blue circles), and course facilitators (white and blue diamonds) using grey arrows to designate a discussion post(s) that was a direct reply to another participant in a discussion thread. The sociogram demonstrates that participants among both PLT and non-PLT groups are distributed around the periphery and also include participants with a greater number of connections concentrated more closely to the center of the graph, or core of the network. However, the figure also helps illustrate that, in proportion to their respective groups, PLT members and leaders are more concentrated towards the center of the graph and have fewer isolates (i.e. participants who posted to a discussion but never received a reply from peers). Only 22.6% of PLT participants who posted in the forums (n=31) appear as isolates in this network, compared to 31.9% of non-PLT forum participants (n=91).

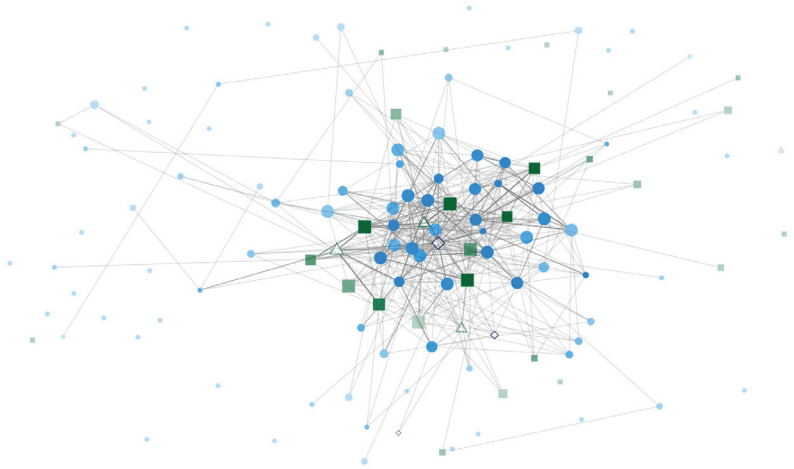

Figure 3. Network graph from Fall 2016 forums showing connections of PLT members (green square), PLT leaders (white and green triangle), non-PLT members (blue circles), and course facilitators (white and blue diamond).

We are particularly interested in how different participants may have been situated in the online community. The concept of social centrality has long been an important structural property of social networks, and measures of network centrality have been positively associated with a range of learning outcomes (Joksimović et al., 2016). For example, Wang (2010) compared differences among five phases of knowledge construction and student's position at the core, core-periphery, and periphery of the network. The author found that the closer participants are to the "core" of a network, the more active they are in the "information- sharing" and "negotiation of meaning" levels of knowledge building. As part of our SNA, we computed measures of centrality for each participant in the 10 discussion forums (two forums in each unit) for Fall 2016. As shown in Table 5 below, the lead course facilitator and the PLT leaders (n=4) demonstrated consistently high scores among four common measures of centrality: degree (in- and out-degree), closeness, and betweenness. In directed networks such as this one, in-degree is often associated with "prestige" or popularity, and in this context is simply a measure of the number of individuals from which a participant has received a response. Out-degree, conversely, is a measure of the number of individuals that a participant has replied through the discussion forums. Finally, closeness centrality measures an individual's potential to connect

easily with other nodes, while betweenness centrality measures their potential to bridge disconnected groups in a network.

Table 5

Network measures for lead facilitator and different groups of forum participants in Fall 2016

Network Measure	Lead Course Facilitator (n=1)	Non-PLT Forum Participants (n = 91)	PLT Leaders (n=4)	PLT Members (n = 27)
In-degree	26	Mean = 4.31 Median = 2 (St.dev. = 4.69)	Mean = 5.5 Median = 5.5 St.dev. = 3.2	Mean = 4.52 Median = 2 (St.dev. = 4.93)
Out-degree	26	Mean = 4.30 Median = 2 (St.dev. = 4.76)	Mean = 7.5 Median = 6.5 (St.dev. = 5.41)	Mean = 4.48 Median = 3 (St.dev. = 3.67)
Closeness	0.007	Mean = 0.0032; Median = 0.0040 (St.dev. = 0.0023)	Mean=0.004 Median=0.005 (St.dev. = 0.0023)	Mean=0.0037; Median = 0.004 (St.dev. = 0.002)
Betweenness	1538.8	Mean = 85.05; Median = 2.76 (St.dev. = 163.47)	Mean = 174 Median = 95.23 (St.dev. = 195.93)	Mean= 60.52; Median= 3.91 (St.dev. = 100.78)

It is not surprising that the lead facilitator (Hollylynne Lee) had significantly higher centrality measures than any other participant group. It *was* surprising to see that PLT leaders, except for one shown as an isolate in the upper right of the sociogram in Figure 3, became socially connected online with many participants, not just those in their PLT groups. The PLT members (n=27) had slightly higher, but overall very similar, centrality measures to the non-PLT online participants. While the mean betweenness value is higher for the non-PLT group (n=91), this is due to a few non-PLT online participants with exceptionally high betweenness values (e.g., 1005.4, 556). Thus, the median values for betweenness are more appropriate to use in comparison, with PLT members having a higher median betweenness score. The centrality measures indicate that in addition to being more active in the forums by posting more (see Table 3), PLT participants (leaders and members) connected to more people, both on the receiving and giving end of discussions, and as a group were more socially connected within the network of all online forum participants.

The analysis of discussion forum data shows us a very clear picture of how enthusiastic many PLT members and leaders were to talk to others in

the online community. They posed their questions and shared ideas with others about teaching statistics throughout the units, even though they were also meeting synchronously several times with their colleagues in small group PLTs. What PLT participants actually discussed in the forums is beyond the scope of this paper but was presented in Akoglu (2018).

Impact as measured on surveys

Participants' survey (unit feedback and end-of-course surveys) responses provide indicators of how valuable the participants perceived the MOOC-Ed experience. A Likert-scale question on the end-of-course survey was: "As a whole, how effective was this MOOC-Ed in supporting your personal and/or professional learning goals?", and the four response choices were scaled from 'not effective' to 'very effective'. Around 90% of both PLT and non-PLT participants responded to this question either with 'effective' or 'very effective'. Similarly, around 90% of both groups responded 'effective' or 'very effective' to the question: "Overall, how effective was this MOOC-Ed in preparing you to make positive changes in your professional practice?" An important question in the last unit feedback survey was asking participants what the most valuable aspect of the MOOC-Ed was. As seen in the examples in Table 6, both PLT and non-PLT members reference specific items from the online course; however, PLT participants' responses also included the role of those PLT meetings and a sense of community (online and in small group) as being very valuable to their experience.

Table 6

Sample responses to question: "What was the most valuable aspect of this MOOC-Ed?"

non-PLT	PLT
Exposure to the framework of statistics and all the different ways to allow students to engage in their own learning as active participants rather than passive ones.	The resources available in the MOOC and the ideas gained from instructors in my group. Doing the MOOC in a group was definitely better than doing it individually. I learned so much more!
The encouragement to use visualization and technology to teach statistical concepts.	The articles, videos, and discussions were very helpful. I was able to build off knowledge from the community found online.
The data sets and articles for follow-up study were great!	PLC meetings where ideas were discussed with colleagues.

The SETS results showed the differences in PLT and non-PLT participants' confidence to teach statistics. Only 50 non-PLT members completed both the pre and post SETS survey (11% of those who began the course), while 28 of the PLT members completed both surveys (46% of those who began the course). Recall, the SETS survey was a self-assessment learning opportunity offered in the course, and not a requirement. Figure 4 illustrates both groups' Pre and Post SETS confidence score, as well as the differences in those scores. This showed us that both groups have an increase in confidence to teach statistics, and that although the non-PLT group has an overall higher increase in confidence, it is not significantly higher (p=0.099). Because of the volunteer and self-selection process, our results are likely biased to represent more of participants in both groups who felt they likely had increased confidence and wanted to take the survey to engage in this self-assessment.

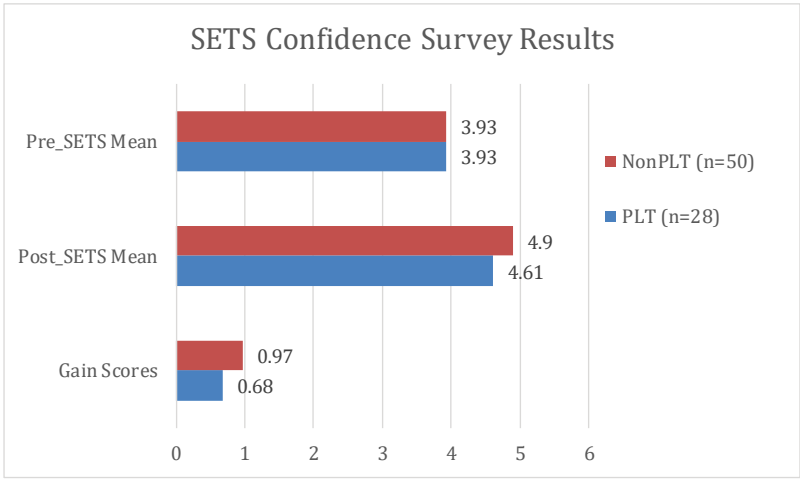

Figure 4. PLT and non-PLT members' SETS results.

There was one open-ended question on the SETS survey for participants to elaborate on factors that affected their confidence. Both PLT and non-PLT participants referenced aspects of the online course that helped them gain confidence, and *none* of the PLT members specifically referenced their experience in a PLT group as impacting their changes in confidence to teach statistics. Thus, while PLT members explicitly referenced community aspects as a valuable part of the course experience on the end-of-course survey, they did not attribute these small group experiences as impacting their confidence to teach statistics.

IMPLICATIONS AND DISCUSSION

MOOCs can be a way to provide online teacher professional development, because such courses help to reach a large number of educational professionals who have a desire to learn about and engage with new strategies and resources (specifically in statistics education for this study). Because the TSDI MOOC-Ed was created for, and advertised to, secondary and post-secondary educators, those that enrolled likely had a genuine interest in learning more about the topic. This likely led to the high rate of enrollees showing up to access some aspect of the course, for non-PLT participants (60.5%) and PLT members (97%). These rates are higher than what has been reported in large scale research on MOOCs, where Jordan (2015) found that across 59 different MOOCs, the typical "show up" rate was near 50% of those enrolled. As typical in open self-directed courses such as MOOCs (e.g., Jordan, 2015, Perna et al, 2014), the number of participants (non-PLT and PLT members) that accessed each unit continued to decrease. However, the number of days visited, interactions in forums, accessing of resources within the course, and completion rates for non-PLT and PLT members were drastically different, with PLT members far more engaged than non-PLT members. Our computation of completion rate aligns with the suggestion from Perna et al. (2014) for computing completion rates, as it eliminates the enrollees that appear to register or come to orientation out of curiosity and keeps participants who seem to intend to start the course to learn the material offered in the course.

Having highly specialized courses for particular audiences may not attract the thousands of enrollees that some MOOCs do, but, such specialized courses may be situated better to at least initially engage their intended audience in early units, and perhaps motivate them to complete the course. As we have shown, a blended approach of having small groups commit to taking an online course together and having small group discussions about course content can dramatically and positively impact the rates of engagement with material, interactions in discussion forums, and course completion. Also, by participating in PLTs, participants were able to interact with others more, both online and in their small group. Thus, being part of a PLT did not deter participants from engaging with others online, but also gave them a way to fill the void of human interaction that others have reported as lacking in MOOCs (Ferdig, 2013). Most PLT leaders and members not only participated as part of a community of practice within their small group but were critical members in the network of participants in the MOOC-Ed, and thus were integrally part of the online community of practice. A subset of

members of both groups (non-PLT and PLT) demonstrated positive changes in their confidence to teach statistics, a major goal of the course. However, PLTs ensured that more participants made it to Unit 5 and likely were encouraged or motivated to engage with the SETS survey to self-assess their growth in confidence.

This research showed the benefits of a blended learning environment in the context of a large-scale effort to engage teachers in considering how to improve their statistics teaching. In this paper we did not dive deep into the ways that PLTs or the MOOC-Ed impacted perspectives on teaching statistics and classroom practices. Results from other comprehensive studies (e.g., Lee, Lovett, & Mojica, 2017; Mojica, Lee, & Lovett, 2018) have shown that the TSDI MOOC-Ed had a strong impact on shifting teachers' perspectives and practices in teaching statistics towards a more active, technology-enabled investigative approach that engaged students with real and sometimes messy data. Further, in the larger study of which this paper is a part, Akoglu (2018) described the lived experiences of the 63 PLT leaders and members and showed how they not only appreciated the support of their local PLT and the online community, but had the same shift in perspectives and practices. PLT members were also able to discuss in their small groups the challenges they would face in enacting changes to their own classroom practices and some PLT members described how they were able to become local change agents in their schools.

The findings suggest having PLTs for supporting a deeper and more comprehensive engagement with online learning materials. MOOC-Eds and other online professional development courses may benefit from purposely suggesting and advertising, and perhaps facilitating, the formation of small face-to-face, or virtual, professional learning teams who commit to engage in an online course together and support one another along the way. School districts interested in the goals of a particular online PD course such as the TSDI MOOC-Ed could partner to provide support in forming local PLTs and awarding additional continuing education credits for those who complete the MOOC-Ed and actively participate in a PLT. Such an approach could be similar to that used by Anderson, Boaler, and Diekmann (2018) where teachers, instructional coaches and administrators are all part of the blended PD experience over an extend period of time. Even without such formal organization at a district level, the PLT leaders in this study demonstrated a high level of commitment and collaboration in their small groups as well as in the online course community.

Mechanisms to develop a sense of community and learning from a small group could also be built into the design of MOOC-Eds or other

online courses for teachers. Aside from asynchronous discussion forums, online course designers could be more purposeful in designing opportunities for synchronous interactions. For example, adding video conferencing, scheduled webinars, or live chat capabilities would allow for participants to join live conversations with others in a course. Offering occasional video-based meetings hosted by a course instructor or other instructional coach or leader may also increase engagement and foster further discussions connected to participants' classroom practices. Use of social media could also help connect participants and extend their collaboration and sense of community outside the boundaries of an online course. Others have found the use of social media such as Twitter, Facebook and Instagram effective ways to sustain an online community of educators that may or may not also be engaged in an online PD experience (e.g., Ferdig et al., 2014; King, 2011; Rothkrantz, 2015). In a 2014 study, Khalil and Ebner found that offering synchronous sessions in a MOOC increased retention and completion rates. Other research mostly focused on synchronous chat sessions, which were usually short and structured, guided by the instructor and/or facilitators of the online course (Hines & Pearl, 2004). On the other hand, according to Coetzee, Fox, Hearst, and Hartmann (2014), the ability to chat live with other participants in a MOOC could provide an advantage for learners. The researchers found that live chat exhibited the predicted advantages over the asynchronous forums and promoted a sense of community. The idea of providing advantages to participants by using an unstructured live chat could be an interesting strategy for a follow-up design and research for providing online professional development for educators that would include both asynchronous communications and synchronous forms of engagement.

While the past decade has seen an increase in development of opportunities for personalized learning for teachers online (e.g., Kleiman et al., 2015; Silverman & Hoyos, 2018), more work is needed to provide additional research-based opportunities, particularly in high-need areas such as statistics and other STEM related areas. The findings from this study can be used to help teacher educators design professional development opportunities that utilize a blended approach of online communities and small groups that can support higher levels of engagement and potential for more sustained local changes in classrooms.

References

Akoglu, K. (2018). *Blending online coursework and small learning communities to examine professional growth in teaching statistics: A phenomeno-*

logical case study (Unpublished doctoral dissertation). North Carolina State University, Raleigh, NC. Available at https://repository.lib.ncsu.edu/handle/1840.20/35014.

Anderson, R., Boaler, J., & Dieckmann, J. (2018). Achieving elusive teacher change through challenging myths about learning: A blended approach. *Education Sciences*, *8*(3), 98.

Avineri, T. (2016). Effectiveness of a mathematics education massive open online course as a professional development opportunity for educators. (Unpublished doctoral dissertation). North Carolina State University, Raleigh, NC.

Avineri, T., Lee, H. S., Lovett, J. N., Tran, D., & Gibson, T. (2018). Design and impact of MOOCs for mathematics teachers. In J. Silverman & V. Hoyos (Eds.), *Distance Learning, E-Learning and Blended Learning of Mathematics: International Trends in Research and Development* (pp. 185-200). Springer: Cham, Switzerland.

Borba, M., Askar, P., Engelbrecht, J., Gadanidis, G., Llinares, S. & Sánchez-Aguilar, M. (2016). Blended learning, e-learning and mobile learning in mathematics education. *ZDM Mathematics Education*, *48*(5), 589-610.

Burgess, T. A. (2011). Teacher knowledge of and for statistical investigations. In C. Batanero, G. Burrill, & C. Reading (Eds.), *Teaching statistics in school mathematics-challenges for teaching and teacher education* (pp. 259-270). Springer, Dordrecht.

Coetzee, D., Fox, A., Hearst, M. A., & Hartmann, B. (2014). Chatrooms in MOOCs: All talk and no action. In *Proceedings of the first ACM conference on Learning@ scale conference* (pp. 127-136). ACM.

Conference Board of the Mathematical Sciences (2012). *The mathematical education of teachers II.* Providence, RI and Washington, DC: American Mathematical Society and Mathematical Association of America.

Dede, C., Ketelhut, D. J., Whitehouse, P., Breit, L., & McCloskey, E. M. (2009). A research agenda for online teacher professional development. *Journal of Teacher Education*, *60*(1), 8-19.

DuFour, R. (2004). What is a "professional learning community"? *Educational Leadership*, *61*(8), 6-11.

Ferdig, R. E. (2013). What massive open online courses have to offer K–12 teachers and students. *Lansing, MI: Michigan Virtual Learning Research Institute. Retrieved May*, *26*, 2014.

Ferdig, R. E., Pytash, K. E., Merchant, W., & Nigh, J. (2014). Findings and reflections from the K-12 teaching in the 21st century MOOC. *Lansing: Michigan Virtual Learning Research Institute Retrieved May 13*, 2015.

Franklin, C., Bargagliotti, A. E., Case, C. A., Kader, G. D., Schaeffer, R. L., & Spangler, D. A. (2015). *The statistical education of teachers*: American Statistical Association.

Franklin, C., Kader, G., Mewborn, D., Moreno, J., Peck, R., Perry, M., & Scheaffer, R. (2007). *Guidelines for assessment and instruction in statistics education (GAISE) report.* American Statistical Association.

Friel, S. N., & Bright, G. W. (1998). Teach-Stat: A model for professional development in data analysis and statistics for teachers K-6. In S. Lajoie (Ed.), *Reflections on statistics: Learning, teaching, and assessment in grades K-12* (pp. 89-11), New York: Routledge.

Harrell-Williams, L. M., Sorto, M. A., Pierce, R. L., Lesser, L. M., & Murphy, T. J. (2015). Identifying statistical concepts associated with high and low levels of self-efficacy to teach statistics in middle grades. *Journal of Statistics Education*, *23*(1).

Harrell-Williams, L. M., Lovett, J. N., Lee, H. S., Pierce, R. L., Lesser, L. M., & Sorto, M. A. (2019). Validation of scores from the high School version of the Self-Efficacy to Teach Statistics instrument using preservice mathematics teachers. *Journal of Psychoeducational Assessment 37*(2), 194-208. Online first in 2017. https://doi.org/10.1177/0734282917735151.

Hasser, N. E. (2017). *Using hybrid MOOCs to improve teachers' academic discourse practices*. Doctoral dissertation, University of California Berkeley. Available online. https://escholarship.org/uc/item/68v894jx

Hawley, W. D., & Valli, L. (1999). The essentials of effective professional development: A new consensus. In G. Sykes, & L. Darling-Hammond (Eds.), *Teaching as the learning profession: Handbook of policy and practice*, (pp. 127-150). New York: Teachers College Press.

Herbst, P., Chazan, D., Chen, C. L., Chieu, V. M., & Weiss, M. (2011). Using comics-based representations of teaching, and technology, to bring practice to teacher education courses. *ZDM*, *43*(1), 91-103.

Herrington, A., Herrington, J., Hoban, G., & Reid, D. (2009). Transfer of online professional learning to teachers' classroom practice. *Journal of Interactive Learning Research*, *20*(2), 189-213.

Herrington, J., Reeves, T. C., & Oliver, R. (2009). *A practical guide to authentic e-learning*. Routledge.

Hines, R. A., & Pearl, C. E. (2004). Increasing interaction in web-based instruction: Using synchronous chats and asynchronous discussions. *Rural special education Quarterly*, *23*(2), 33-36.

Joksimović S., Manataki, A., Gašević D., Dawson, S., Kovanović V., & De Kereki, I. F. (2016). Translating network position into performance: importance of centrality in different network configurations. In *Proceedings of the sixth international conference on learning analytics & knowledge* (pp. 314-323). ACM. http://doi.org/10.1145/2883851.2883928

Jordan, K. (2015). Massive open online course completion rates revisited: Assessment, length and attrition. *The International Review of Research in Open and Distributed Learning*, *16*(3).

Kellogg, S., & Kleiman, G. (2018). *MOOC-Ed evaluation summative report.* Raleigh, NC: Friday Institute for Educational Innovation.

Khalil, H., & Ebner, M. (2014). MOOCs completion rates and possible methods to improve retention-A literature review. In proceedings of *EdMedia: World Conference on Educational Media and Technology* (pp. 1305-1313). Association for the Advancement of Computing in Education (AACE).

King, K. (2011). Professional learning in unlikely spaces: Social media and virtual communities as professional development. *International Journal of Emerging Technologies in Learning*, *6*(4), 40-46.

Kleiman, G., & Wolf, M. A. (2015). Going to scale with online professional development: The Friday Institute MOOCs for Educators (MOOC-Ed) initiative. *North Carolina State University College of Education*. http://fi-courses.s3.amazonaws.com/blog/going-to-scale-with-oTPD.pdf.

Kleiman, G., Wolf, M.A., & Frye, D. (2015). Educating educators: Designing MOOCs for professional learning. In Kim, P. (Ed.), *Massive Open Online Courses: the MOOC Revolution* (pp. 117-144). New York: Routledge.

Lantz-Andersson, A., Lundin, M., & Selwyn, N. (2018). Twenty years of online teacher communities: A systematic review of formally-organized and informally-developed professional learning groups. *Teaching and Teacher Education*, *75*, 302-315.

Leavy, A. M., Hannigan, A., & Fitzmaurice, O. (2013). If you're doubting yourself then, what's the fun in that? An exploration of why prospective secondary mathematics teachers perceive statistics as difficult. *Journal of Statistics Education*, *21*(3).

Lee, H. S., Lovett, J. N., & Mojica, G. M. (2017). Characterizing impacts of online professional development on teachers' beliefs and perspectives on teaching statistics. In E. Galindo & J. Newton (Eds.), *Proceedings of the 39th annual meeting of the North American Chapter of the International Group for the Psychology of Mathematics Education* (pp. 407-414). Indianapolis, IN: Hoosier.

Lee, H. S., & Stangl, D. (2015). Taking a chance in the classroom: Professional development MOOCs for teachers of statistics in K-12. *Chance*, *28*(3), 56-63.

Lee, H. S., & Stangl, D. (2017). Design and implementation of professional development MOOCs for teachers of statistics. *AMSTAT News (Special issue on Statistics Education),* September, Available online: http://magazine.amstat.org/blog/2017/09/01/pd_teachers/.

Lieberman, A., & Pointer Mace, D. H. (2008). Teacher learning: The key to educational reform. *Journal of Teacher Education*, *59*(3), 226-234.

Lock, J. V. (2006). A new image: Online communities to facilitate teacher professional development. *Journal of Technology and Teacher Education*, *14*(4), 663-678.

Lovett, J. N., & Lee, H. S. (2017a). New standards require teaching more statistics in high school: Are preservice mathematics teachers ready? *Journal of Teacher Education 68(3)*, 299-311.

Lovett, J. N., & Lee, H. S. (2017b). Incorporating multiple technologies into teacher education: A case of developing preservice teachers' understandings in teaching statistics with technology. *Contemporary Issues in Technology and Teacher Education*, *17*(4), 440-457.

Lovett, J. N., & Lee, H. S. (2018). Preservice secondary mathematics teachers' preparedness to teach statistics: A call for reform. *Journal of Statistics Education 26*(3), 214-222. https://doi.org/10.1080/10691898.2018.1496806

Luebeck, J., Roscoe, M., Cobbs, G., Diemert, K., & Scott, L. (2017). Re-envisioning professional learning in mathematics: Teachers' performance, perceptions, and practices in blended professional development. *Journal of Technology and Teacher Education, 25*(3), 273-299.

Mackey, J., & Evans, T. (2011). Interconnecting networks of practice for professional learning. *The International Review of Research in Open and Distributed Learning*, *12*(3), 1-18.

Makar, K., & Fielding-Wells, J. (2011). Teaching teachers to teach statistical investigations. In C. Batanero, G. Burrill, & C. Reading (Eds.), *Teaching statistics in school mathematics – Challenges for teaching and teacher education: A Joint ICMI/IASE Study* (pp. 347–358). New York: Springer.

Marrongelle, K., Sztajn, P., & Smith, M. (2013). Scaling up professional development in an era of common state standards. *Journal of Teacher Education*, *64*(3), 202-211.

Mojica, G., Lee, H. S., & Lovett, J. (2018). Designing spaces to support teacher learning about teaching statistics. In Hodges, T.E., Roy, G. J., & Tyminski, A. M. (Eds.). *Proceedings of the 40th annual meeting of the North American Chapter of the International Group for the Psychology of Mathematics Education (*pp 410 – 413). Greenville, SC: University of South Carolina & Clemson University.

National Council of Teachers of Mathematics. (2000). *Principles and standards for school mathematics.* Reston, VA: Author.

Common Core State Standards Initiative. (2010). *Common core state standards for mathematics.* Washington, DC: National Governors Association Center for Best Practices and the Council of Chief State School Officers.

Newman, M. E., & Park, J. (2003). Why social networks are different from other types of networks. *Physical Review E, 68*(3), 036122.

Owston, R. (1998). *Making the link: teacher professional development on the internet*. Portsmouth, NH: Heinemann, A Division of Reed Elsevier, Inc.

Perna, L. W., Ruby, A., Boruch, R. F., Wang, N., Scull, J., Ahmad, S., & Evans, C. (2014). Moving through MOOCs: Understanding the progression of users in massive open online courses. *Educational Researcher*, *43*(9), 421-432.

Rothkrantz, L. (2015). How social media facilitate learning communities and peer groups around MOOCS. *International Journal of Human Capital and Information Technology Professionals*, *6*(1), 1-13.

Scott, J. P. (2000). *Social network analysis: A handbook.* SAGE Publications Ltd.

Seaton, D. T., Coleman, C., Daries, J., & Chuang, I. (2015). Enrollment in MITx MOOCs: Are we educating educators? *EDUCAUSE Review*. Retrieved from: https://er.educause.edu/articles/2015/2/enrollment-in-mitx-moocs-are-we-educating-educators.

Silverman, J., & Hoyos, V. (Eds.). (2018). *Distance learning, E-learning and blended learning in mathematics education: International trends in research and development.* Springer.

Sprague, D. (2006). Research agenda for online teacher professional development. *Journal of Technology and Teacher Education*, *14*(4), 657-661.

Vrasidas, C., & Zembylas, M. (2004). Online professional development: Lessons from the field. *Education Training, 46*(6/7), 326-334.

Wang, L. (2010). How social network position relates to knowledge building in online learning communities. *Frontiers of Education in China, 5*(1), 4–25. doi:10.1007/s11516-010-0003-4.

Wasserman, S., & Faust, K. (1994). *Social network analysis: Methods and applications*. Cambridge University Press.

Wenger, E. (2011, October). *Communities of practice: A brief introduction*. Retrieved from http://hdl.handle.net/1794/11736.

Wenger, E., McDermott, R. A., & Snyder, W. W. (2002). *Cultivating communities of practice: A guide to managing knowledge.* Boston, MA: Harvard Business School Press.

Wiebe, E., Thompson, I., & Behrend, T. (2015). MOOCs from the viewpoint of the learner: A response to Perna et al. (2014). *Educational Researcher*, *44*(4), 252-254.

Zazkis, R., & Herbst, P. (Eds.). (2017). *Scripting approaches in mathematics education: Mathematical dialogues in research and practice*. Springer.

Author Note

The *Teaching Statistics Through Data Investigations* MOOC-Ed was developed and offered through funding from the William and Flora Hewlett Foundation awarded to the Friday Institute for Educational Innovation at NC State University. The implementation of a blended professional development was funded through a member initiative grant by the American Statistical Association to Hollylynne Lee. The research findings and opinions reported in this paper are those of the authors and not necessarily those of the funding sources. The research in this paper is partially based on the dissertation of Kemal Akoglu under the direction of Hollylynne Lee at NC State University.

APPENDIX A

Sample Guide for a Unit in MOOC-Ed

Unit 2: Engaging in Statistics
Facilitated Session Guide

Use the facilitation guide designed specifically for the unit your team is working on. The guide includes time estimates and is intended to help your group synthesize the ideas in the course and make plans for how to implement new strategies in your classroom in order to impact students' learning of statistics. We encourage you to engage in the conversations and group activities that best meet your group's needs.

COMPLETE PRIOR TO SESSION:
Watch the Hear From Your Instructor video, engage with all materials in the Essentials, and watch the Learn From Our Expert Panel video(s). Individuals may also engage with the Dive Into Data and Investigations before the session, or you could choose to do those together and extend the time allotted.

I. BIG IDEAS: (10-15 minutes)
Facilitate a discussion with your colleagues to consider what they are learning about the following big questions (posed in the Hear from Instructor video)

- What is a statistical investigation?
- What are statistical habits of mind?
- What is the difference between mathematics and statistics?
- What are the features of tasks that can engage students in statistics?

If the group wants to discuss the Essentials and Expert panel videos, consider the following prompts:

- *Statistical Habits of Mind*: How can developing statistical habits of mind help you and your students use and apply statistics and statistical thinking?
- *The Difference between Statistics and Mathematics*. What are differences and similarities between statistics and mathematics? Why does it matter that we make a distinction?
- *Statistical Analysis to Rank Baseball Players*. What about the video intrigued you most?

- *Written Statistics Task Guide*. Analyze the lesson or worksheet that you brought to the meeting using the statistics task guide. What components of the lesson or questions posed to students could be improved that would better engage students in statistical habits of mind and the four phases of an investigation?
- *Focusing on the Expert Panel:* After listening to the Expert Panel's discussion on statistical investigations, how does that compare with your previous experiences teaching and learning statistics? What struck you about the Expert Panel's discussion of how mathematics and statistics are different?

II. DIVE INTO DATA: (10-20 minutes)
This data experience uses data preloaded into two free online tools, TUVA and CODAP. The TUVA interactive graph includes data about movies from two animation film studios, Pixar and Dreamworks, to explore their budget, profits, ratings, and release dates. The CODAP site includes tracking data from four elephant seals to explore variables such as location, distance traveled, speed, and water depth. If participants have not already engaged in this activity, allow 10 minutes for them to explore the specific task posed on the Dive Into Data page. If you have already completed this activity individually prior to coming together, share your strategies and responses.

- What surprised you about your experience exploring these data with these online graphing tools?
- How did having a rich context for the data impact your engagement and reasoning?

If interested, encourage participants to explore other preloaded data sets from TUVA and CODAP. Teachers can register for accounts at these two sites and then upload their own data sets.

III. INVESTIGATION: (30 minutes)
Choose to either analyze the set of 3 tasks for middle school, or the 3 tasks for high school, or both. For each task, discuss the following questions.

- What learning goal(s) could this task be used for students' learning?
- Is this task worthwhile to engage students in statistics through all or parts of an investigation cycle?
- Could this task promote productive statistical habits of mind?
- What would you change about this task to make it more worthwhile? why?

IV. REFLECTION & NEXT STEPS (5 minutes)
Point out the Extension Resources, specifically Mathematical Practices through a Statistical Lens, the lesson plans, and Suggested Resources for Difficult Topics (lots of great links that can assist you and your students in learning some difficult statistics topics).

- What is exciting you about considering Statistical Habits of Mind when designing lessons for your students?
- What have you started formulating for how you might implement ideas and resources from this unit in your practice?

V. FORUM DISCUSSIONS
What ideas or issues emerged in the discussion forums this past week? What would our group members like to contribute in the forums to hear the ideas/opinions of others?