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DESIGN AND IMPACT OF MOOCS FOR MATHEMATICS TEACHERS

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With online learning becoming a more viable and attractive option for students and teachers around the world, we discuss how one effort in the U.S. is focused on designing, implementing, and evaluating MOOCs designed for professional development of mathematics teachers. We share design principles and learning opportunities, and discuss how these MOOCs have impacted engagement of educators, and impacts participants report for changes to teaching practices.

Improving mathematics and statistics instruction continues to receive attention around the globe, and many efforts have been made to design professional development for teachers to develop their content and pedagogy, typically on a small local scale (cf. Darling-Hammond et al., 2009). Online courses can expand the reach of professional development and the teachers involved, fostering communities beyond school or district lines. Indeed, with advances in technology and interest in offering alternatives to traditional professional development (e.g., in-person conferences, workshops), the number of online professional development opportunities has increased. The National Research Council (NRC, 2007) claimed that:

> The provision of professional development through online media has had a significant influence on the professional lives of a growing number of teachers. Growing numbers of educators contend that online teacher professional development (OTPD) has the potential to enhance and even transform teachers' effectiveness in their classrooms and over the course of their careers. (p. 2)

Most recently, with increased demand for open and accessible resources and advances in technological and analytic capabilities, Massive Open Online Courses (MOOCs) have become a significant option for online education internationally (Pappano, 2012). MOOCs are designed and delivered in a variety of ways, depending on the learning goals for participants, to serve different target populations and provide diverse experiences for learners (Clark, 2013). Most MOOC participants engage in isolation, reviewing material individually and *perhaps* engaging in discussion forums (Kim, 2015). In recognizing the potential for MOOCs to serve as large-scale professional development, we are part of teams that have created MOOCs for Educators (MOOC-Eds) to assist mathematics and statistics teachers in developing content understanding and pedagogical strategies for improving practice, and forming local and global communities of educators. Our question guiding this design and research is "*To what extent does a MOOC offer opportunities for mathematics and statistics teachers to engage in professional learning and impact their practices*?"

DESIGN OF COURSES

The MOOC-Ed effort at the Friday Institute for Educational Innovation (www.mooc-ed.org) includes a collection of courses built using design principles of effective professional development

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.

Thus far, two of the MOOC-Eds focus on mathematics and statistics education, *Fraction Foundations* and *Teaching Statistics through Data Investigations*. The *Fraction Foundations* MOOC-Ed was designed to help K-5 teachers teach fraction concepts and skills through understanding students' thinking and implementing research-based approaches in classrooms aligned with recommendations of a practice guide for developing effective fraction instruction (Siegler et al., 2010). The purpose of the *Teaching Statistics* course was for participants to think about statistics teaching in ways likely different from current practices in middle school through introductory statistics. A major goal was for teachers to view statistics as an investigative process (pose, collect, analyze, interpret) that incorporates statistical habits of mind and view learning statistics from a developmental perspective, aligned with guidelines from Franklin et al. (2007).

The following examples illustrate how we enacted two design principles--self directed learning and learning from multiple voices--in these two courses. We promoted *self-directed learning* by encouraging participants to set their personal learning goals at the beginning to help guide their experience. For example, in the *Teaching Statistics* MOOC-Ed, participants engaged with a confidence rating survey for their statistics teaching efficacy, and in *Fraction Foundations* participants engaged with approximately 30 items to consider their awareness of different mathematical and pedagogical issues in teaching fractions. In each course, multiple types of resources were incorporated, such as classroom-ready materials (e.g., lesson plans, tasks, content instructional videos) and thought-provoking materials for educators to reflect on their practice and deepen their content and pedagogy knowledge for teaching. These resources were often provided with multiple media, such as readings/transcripts, classroom videos, animated videos, and podcasts to support different paths of learning activities. Participants were also often given choices to explore materials designed for different levels of understandings or grade levels. In addition, the project component of each course was designed to suit a teacher's practice or to assist other educators, such as mathematics coaches, professional development providers, and mathematics teacher educators, in developing their own materials for use in professional development settings.

Both courses incorporated a number of opportunities to *learn from multiple voices*. As members of the design teams, we created many of our own resources, but also used existing open access resources written by other educators in the respective disciplines. Discussions that included well-known experts in the respective disciplines were recorded and used throughout the courses. In these videos, the experts discuss relevant topics, share personal experiences and valued resources, and suggest strategies for implementing knowledge gained from research in everyday classrooms (see Figure 1a). The discussion forums were designed for participants to post their thoughts about videos and discussion prompts, as well as interact with others, including facilitators of the courses. The design teams function as facilitators in forums; we encourage participants to share experiences and connect similar threads from different groups to offer multiple perspectives purposed to support richer discussions. Student voices were brought into courses through student interviews edited to highlight specific student thinking (see Figure 1b), videos of teachers and students engaged in tasks in classrooms, and through animated videos based on actual student responses to research tasks.

Figure 1: (a) Experts discussing an issue, and (b) a group interview of students working on a task.

LEARNING OPPORTUNITIES IN THE MOOC-EDS

Both courses are built upon research-based recommendations for effective teaching in the specific content areas. All resources included in the courses center around and explicate the recommendations through short videos, documents and experiences that are applicable for educators. In the *Fraction Foundations* course, many activities are built using the recommendations in the Siegler et al. (2010) report on effective instruction on fractions. For example in a unit about using fair sharing activities to build up understanding about fractions, the *What Would You Do Next?* videos of students working on fair sharing tasks with an interviewer prompt for participants to examine the students' understanding and how they would help move students forward. Core resources included research-based recommendations for using fair sharing activities in teaching fractions, and other resources to support the teaching of the concepts focusing on student thinking. In addition, participants could engage with expert panel videos to hear experts discussing teaching approaches for fair-sharing and measurement activities to build up conceptual understanding and procedural fluency for fractions. Discussion forums enabled participants to focus on their reflection on their successes as well as challenges when teaching specific fraction constructs.

In the *Teaching Statistics* course, we used research on students and teachers' learning of statistics and teaching practices to build opportunities for engagement. For example, we built upon an existing framework (GAISE, Franklin et al., 2007) by incorporating recent research on students' statistical thinking and highlighting productive statistical habits of mind. Our new framework, Students' Approaches to Statistical Investigations [SASI], needed a variety of learning materials and opportunities for participants to develop an understanding of its importance and potential ways it can influence their classroom practices. Both a static and interactive version of a diagram was created to communicate the investigative cycle, reasoning in each phase at three levels, and an indication of productive habits of mind for each phase. 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 one of the experts illustrating the development of the concept of *mean* across levels of sophistication. –The participants could also watch two animated illustrations of students' work on a task that highlighted how students could approach an investigative task using different levels of statistical sophistication and then discuss, in the forums, students' work and how they could use such a task in their own practice.

DATA COLLECTION AND ANALYSIS

Data included registration and click logs of every action taken by participants (e.g., resources viewed, videos watched). All dialogs generated in discussion forums, 5-star ratings of resources, and feedback surveys were collected. Descriptive statistics were generated based on demographic

information, survey responses, and click logs. Open coding of forums and survey responses was used to develop themes related to impacts on practice, as discussed below. For the Fractions Foundations course, follow-up interviews and classroom observations were used to ascertain impacts of the learning opportunities on teachers' classroom practices.

ENGAGEMENT IN THE MOOCS

Although both courses have been offered more than once, we will focus on the course offerings that occurred in Spring 2015. There were 1712 participants registered for the *Fraction Foundations* (FF) course, with 34 countries represented (vast majority were US based, 93%) while the *Teaching Statistics* (TS) course had 797 participants registered from 43 countries, with 597 (76%) registrants from the U.S. Figure 2 illustrates our global reach for both courses in Spring 2015. In both courses, the majority of participants were classroom teachers (58% FF and 64% TS). Both courses also had about 10% of participants that worked in mathematics teacher education in university settings or other professional development roles. Interestingly, about two thirds of participants in both courses held advanced degrees (masters or doctoral). This is one indicator that many attracted to the MOOC-Eds were engaged learners in their discipline, valuing advanced educational opportunities.

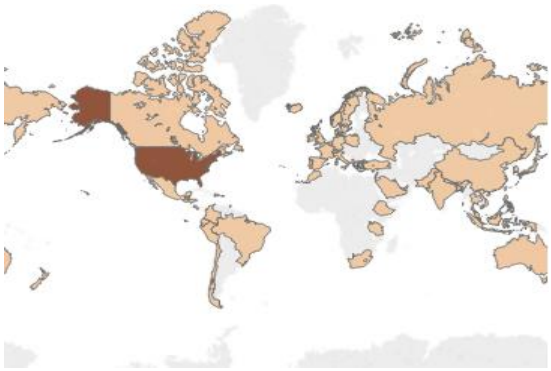

Figure 2: Global enrollment in both MOOC-Ed courses Spring 2015.

The graph in Figure 3 illustrates the engagement of those who enrolled. Participants were considered "no shows" if they never entered the course after registration, and were tagged as a "visitor" if they logged into the course and engaged with some aspect of it four or fewer times (Kleiman, Kellogg, & Booth, 2015). The remaining participants who engaged were considered active participants. As the graph indicates, there is a large proportion of registrants (1/4 to 1/3) that do not ever engage. However, in both courses, there was a large number that engaged somewhat and more fully. While these numbers may not look impressive for a massively scaled course, in the context of professional development, the materials are potentially impacting a large number of participants. Additional analysis was done by Kleiman et al. (2015) that further characterized the active participants according to how engaged they were throughout the course with videos, resources and tools, visiting discussion forums, posting in forums, and commenting on posts of others. This analysis showed that the 547 active participants in the *Fractions Foundations* course were about equally categorized as declining activity (34%), moderate activity (38%), and sustained high activity (28%). However, the 180 active participants in the *Teaching Statistics* course had either declining activity (54%), or sustained high activity (46%). These high activity rates, through the final units in the courses, is much higher than typical MOOC completion rates (2-10%), but is aligned with completion rates when participants intend to complete a course (Reich, 2014).

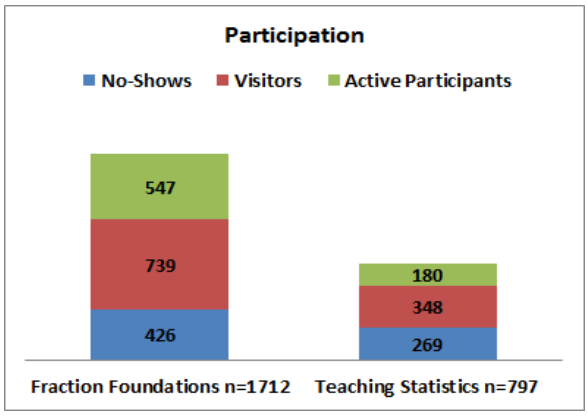

Figure 3: Distribution of participation categories in both MOOC-Ed courses Spring 2015.

One way that MOOC-Eds differ from other MOOCs is the intentional design to create and support a network of professional learners. This is mainly accomplished through opportunities to interact with one another in discussion forums. There were about 33% of participants (visitors or active participants) who posted at least twice in the forums with either a new post or comment on a post of a peer; however, Kleiman et al. (2015) identified many participants across both courses that were considered to be active contributors to the discussion forums. In *Fraction Foundations*, there were 770 participants (59.9% of 1286 visitors or active participants) who contributed in some way in the forums, with an average of 9.3 posts per participant. In *Teaching Statistics*, 308 (58.3% of the 528 visitors or active participants) participated in the forums with an average of 7.1 posts each. Examining click logs, we found there were also *many* more discussion views than postings. Some discussion views were done by participants who were active posters; however, other views were done by non-posters. Thus, many saw discussion forums as an opportunity for learning, even for just reading the posts of others. Participants who engage in such "lurking" are present, but not visible; thus, exactly why they read discussions and what they have learned from them is unknown.

IMPACT OF THE MOOC-EDS ON EDUCATORS' PRACTICES

On end-of-course surveys, participants were asked how effective they felt the MOOC-Ed was in preparing them to make positive changes in their practice. Across the two courses, 205 participants completed the optional end of course survey, with 96.5% of participants responding positively. Participants were then explicitly asked if they had made changes in their practice as a result of participation, to which 96.7% indicated "Yes." When asked to describe how they were applying what they learned to their professional practice, participants typically responded by citing one of the following: 1) integrating new tools and strategies, 2) implementing course projects, and 3) using course content for instructional coaching or professional development with colleagues.

For both courses, we examined discussion forum posts and open-ended responses on feedback surveys to look for explicit mention of changes to practice and tagged triggers for such changes. Preliminary analysis shows there were several main themes and course triggers that participants indicated as leading to changes in practice. In the *Teaching Statistics* course, four elements emerged as often cited for triggering impacts on practice. The most dominant trigger for change was the SASI framework. Not only did participants discuss how they needed to design tasks that met their students where they were, but also to further develop their levels of sophistication. Educators also reported wanting to use all four phases of a statistical investigation, rather than their past heavy

emphasis on the analysis phase. Two additional common triggers were the use of technology for visualizing data, and use of real data sources that are multivariable and sometimes "messy". These triggers came from learning opportunities in the course that included videos of students and teachers engaged with messy data using technology, discussions in expert panel videos, and opportunities to use a large internet resource for gathering and sampling data from students across the world (Census at School) and a technology tool of their choice to engage with the data. Consider the following statements from participants with course triggers bolded:

> I have changed my planning process for statistics. I will use more **technology** in my teaching and spend more time on the **first 2 phases of the investigative cycle**. I will encourage **statistical habits of mind** and movement through the **levels of the SASI framework.**
>
> The **SASI framework** was the most useful part of the course. It is incredible. I've been telling the teachers here about it because normally we teach the Intro to Stats class only procedurally, **just calculations, with no sense of equations or interpreting**. But that has changed now because of using the framework.
>
> Since starting the class, I have had my students use **richer and messier data** in their investigations and I have also put **more of an emphasis on understanding the results** and being able to analyze findings.

While some of the comments indicate how teachers have already changed, or will change, their practices with their own students, other comments show how elements of the *Teaching Statistics* course is impacting how participants encourage their colleagues to change their practices.

In the *Fraction Foundations* course, the themes related to impact on practice were: attending to student conception and misconception, prompting students to elicit reasoning, using multiple representations and models to help students understand fractions, and designing/adapting rich tasks to assess students' understanding. These themes are associated with triggers from course experiences, such as the student interview videos, the tasks provided, and conducting a clinical interview as part of a project. Consider the following participant statements with course triggers bolded:

> I now really talk to the students and have **interviews** so I can assess better. I look at fractions in a whole different way. I also look closer at **student answers, I once would have considered incorrect**.
>
> The most valuable part of this MOOC-Ed was the "**What Would You Do Next?" video series**. As teachers, I think we need to see the "look fors" in students' misconceptions… For students to understand, teachers must become comfortable **seeing misconceptions** and addressing the understanding.
>
> I have begun to facilitate **learning of fractions versus teaching the students about fractions**. I am now having students take their time and **explore concepts in different ways** rather than rushing through and trying to teach an algorithm.

While some participants' comments address changes to their approach to teaching (e.g., increased focus on concepts as opposed to algorithms), others describe how their participation supported their refined attention to and understanding of their students' thinking and their own personal improvement in knowledge of mathematics. This finding was supported by classroom observations and interviews with teachers who participated in the *Fraction Foundations* courses (Avineri, 2016).

Indeed, in describing her lesson planning after having participated in the MOOC-Ed, one teacher noted that the course encouraged her to:

> [try] to do something different on purpose. Trying not to drag out my old fraction folder and dig from it. Trying to do something other than I would normally have done...It has impacted me to just slow down. It's not a race. You have to strategically take your time and give them a chance to develop that knowledge, to start small and then let it blossom.

This was evident in observations of this teacher's classroom following the MOOC-Ed. Another teacher described how her enhanced mathematical understanding impacted her attention to her students' thinking, which was also evident in classroom observations following the MOOC-Ed.

> I just wanted a better understanding of what a fraction was, what it meant to partition…and then to see [the students] today, "Well you've got four more models, that's your four wholes that are represented, but you've got a fourth of each one or a third of each one"...I would never have looked for that conversation from them before.

DISCUSSION

The results are encouraging for how participants took advantage of our purposeful designs. There were many elements of these designs that acted as catalysts for self-reflection and change in practice. The use of frameworks and research-informed practices in teaching both fractions and statistics were highly valued and appear to assist participants in viewing the learning and teaching of these ideas more conceptually and comprehensively. Activities that were designed to capture the perspective of students such as, What Would You Do Next? videos, videos of students' work in classroom, and edited and produced videos of students' work from research all fostered rich discussions in the forums about students' understandings and how participants can use their new understanding of students' reasoning to inform instructional planning. Participants also seemed to be able to shift their perspectives from viewing the importance of teaching and learning these content ideas as reliant on algorithms or procedures, to a view of mathematics and statistics as more of a process that has nuanced conceptions that must be developed with extended experiences.

Too often, professional development is provided by local school districts and does not meet individual teacher's need (Sowder, 2007). However, our MOOC-Eds provided participants the opportunity to engage in professional development to strengthen their content and pedagogy in areas of mathematics *they personally were interested in improving*. In the forums, one participant discussed the opportunities she felt the MOOC-Ed provided:

> Some all day workshops can be painful and provide little benefit. I think teachers who have given up instructional time and been burned on a poorly designed workshop become increasingly resistant to later PD opportunities. This course has been just the opposite. I can engage with it on my own schedule, rather than losing class time, and I'm coming away with lots of new ideas, resources, and activities. I feel grateful for this opportunity and look forward to finding more like it.

The design principles that guide the creation of these courses have afforded educators choice in professional learning, complemented with relevant, job-embedded activities, access to the perspectives of experts, teachers, and students, and a network of educators learning together around a common content area. We continue to learn about the affordances and constraints of this model of professional learning for mathematics teachers and are interested in expanding our research. One

expansion needed is to explore long term impacts on practice. There is also a need to explore the potential of MOOC-Eds beyond our current implementation model as time-bound courses managed primarily by our team. If the MOOC-Ed courses were available on-demand, how would participants engage, and would professional learning networks emerge? We would like to explore the possibility of international collaboration in the design of future courses, the impact of facilitators in a course of this scale, and the possibility of offering smaller scale modules that are continuously available.

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