DESIGNING FOR EDUCATORS IN A TEACHING STATISTICS MOOC: DESIGN PRINCIPLES AND USE OF MULTIMEDIA TO SUPPORT PARTICIPANT ENGAGEMENT

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Though many MOOCs exist for learning statistics and data science, very few exist for learning to teach statistics to students from adolescents to adults. Designing a course for professional educators is fundamentally different than designing for learners of statistics. We present four design principles enacted in the Teaching Statistics Through Data Investigations MOOC for Educators. We discuss results of implementation from six offerings in 2015-2017, including characteristics of the 2525 enrollees from around the world, their patterns of engagement, and key ways the design principles impacted their experiences. We focus on how use of multimedia to communicate a framework about supporting students' approaches to statistical investigations impacted participants' learning and how they viewed the framework as useful for their practice.

NEED FOR MOOC ON TEACHING STATISTICS

Statistics has gained a prominent place in secondary and post-secondary curricula in many countries, including the U.S. (e.g., Franklin et al., 2007; Franklin et al., 2015). Across the globe, the possibilities of online learning paved the way for many Massive Open Online Courses (MOOCs) and other distance course offerings. For *learning statistics*, options abound for courses in which a learner can develop knowledge in statistics. Two examples include the Data to Insight course led by Chris Wild at University of Auckland in New Zealand (www.futurelearn.com/courses/ data-to-insight), and a five-course sequence in a statistics specialization developed by a team led by Mine Çetinkaya-Rundel at Duke University in the U.S. (www.coursera.org/specializations/statistics). However, online courses designed for *learning to teach statistics*, are relatively rare.

Franklin et al. (2015) call for greater attention to the statistical education of teachers, including inservice teachers. Professional development (PD) for secondary teachers to develop their statistical content and pedagogy are being offered across the world, typically on a small local scale, and these often include focused evaluation and research efforts to document impacts. However, the need for preparing teachers to teach statistics is much bigger than what can be addressed with small local programs. For example, in Germany, Biehler (2016) has led development and implementation of PD for secondary teachers that started on a smaller scale and expanded to reach many more teachers in Germany. Two efforts to offer MOOCs on learning to teach statistics, with very different approaches, have been developed in the U.S. A course designed by a team led by Dalene Stangl at Duke University, only offered once through Coursera, focused on increasing teachers' content knowledge and technological skills with dynamic statistics software. At NC State, Hollylynne Lee led a team in developing a course for educators focused on pedagogical approaches to teaching statistics, including the use of an investigative cycle, real data, and software tools. See Lee and Stangl (2015; 2017) for more information. The latter course, *Teaching Statistics through Data Investigations [TSDI]*, is the focus of this paper.

DESIGNING FOR ONLINE LEARNING

The increase in availability of different online learning platforms, wider broadband access to the internet (though still not accessible in many countries), and improved tools for creating interactive and multimedia resources, has afforded online course designers many options for ways to provide content and learning experiences. While a complete review of aspects of online learning and teaching are not possible in this paper, a few recommendations from results of studies are helpful to situate the development of the multimedia resources in the TSDI MOOC for Educators. Much of the learning opportunities in MOOCs are highly focused on the individual, with most learners working asynchronously, in isolation. Thus, the design of learning opportunities matters for promoting engagement, retention, and application to practice.

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The work of Mayer and Moreno (2003) has been highly influential over the past 15 years in informing the development of multimedia designs in resources used in online courses. Their work on dual channel processing specifically examined issues of cognitive load when certain multimedia designs were enacted and made suggestions for designs that could reduce cognitive overload, and thus promote better learning opportunities. For example, they found that having printed words spatially separated from parts of a diagram was confusing and increased processing time. They suggest placing printed words near corresponding parts of any graphics to reduce time for visual scanning. They also suggest presenting narrated explanation and animated graphics used to illustrate a concept simultaneously so that learners did not have to hold representations or graphics used in an animation in memory to recall later with an explanation.

In examining three popular MOOCs, Hew (2014) found several factors that impacted participants' positive engagement in courses: (1) problem-centric learning with clear expositions, (2) instructor accessibility and passion, (3) active learning experiences, (4) opportunities for peer interaction, and (5) using helpful course resources. For example, learners reported positively about course videos with clear content presentations, showing an instructor's passion for the subject and that prompted active learning experiences with the content. Specifically related to the use of videos in MOOCs, Guo, Kim, and Rubin (2014) found, among other things, that shorter videos are much more engaging, videos that intersperse an instructor's talking head with slides showing content are better than slides alone, and videos where instructors speak at a faster rate with enthusiasm promote engagement. Laasar and Toloza (2017) also discuss how video is changing online learning and discuss how new capabilities in created animated videos, such as complete stop-motion animations, or animated agents overlayed on slides (rather than instructor picture-in-picture), can create engaging learning opportunities. Aligned with Hew (2014) and others, designers of online courses should build infrastructure to support active learning and peer interaction across geographic and time zone boundaries. Within online professional development for educators, asynchronous discussion forums, for example, provide opportunities for participants to reflect on practice, exchange ideas, and discuss ways to improve on their own schedules with colleagues with whom they may not otherwise interact (Treacy, Kleiman, & Peterson, 2002).

DESIGN OF COURSE

At the Friday Institute for Educational Innovation at NC State University, the MOOCs for Educators consists of a collection of courses built using research-based 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. The TSDI course (http://go.ncsu.edu/tsdi) aims to have participants think about statistics teaching and learning in ways likely different from current practices in middle school through college-level introductory statistics. The course does not focus on a particular grade band or specific statistical content. A major goal is for teachers to be introduced to and use a framework for teaching statistics as an investigative process that incorporates statistical habits of mind and view learning statistics from a developmental perspective (aligned with Franklin et al., 2007).

The design principle of *learning from multiple voices* is enacted through videos of an Expert Panel discussion with the instructor and three experts in statistics education. Multiple voices were also present with the use of classroom videos with teachers and students engaged in statistics tasks using technology. Several examples of students' work (based on research literature) were developed into animated illustrations (using Go Animate or Powtoon) that represented students' statistical reasoning and use of technology. *Self-directed* and *job-connected* learning opportunities included Dive Into Data experiences in each unit for participants to use a variety of free technology tools (e.g., Gapminder, Tuva, CODAP, GeoGebra simulations) or import data into their favorite tools, such as Fathom, StatCrunch, JMP. These experiences allowed teachers to use tools accessible in their schools and connected them to free sources of data that can be useful in their lessons. For example, in Unit 4, the Dive Into Data uses the Census at Schools website to engage teachers in a cycle of statistical investigation. Extensions in each unit include extra resources (e.g., data sets, lesson plans, brief articles, java applets, additional videos) and provide opportunities to explore content and resources of interest to them. *Peer-supported* learning is a cornerstone of the MOOC-

Ed experience. Each unit contains two discussion forums: 1) a forum focused on discussing specific pedagogical 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.

MULTIMEDIA DESIGNS FOR LEARNING THE FRAMEWORK

Because of its importance in the course, we provide details about the major framework that was developed and integrated across the course. Building upon an existing framework (Franklin et al., 2007), the development team incorporated recent research on students' statistical thinking and productive statistical habits of mind. The 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. To illustrate the multimedia approach to providing learning opportunities in the course, we describe some of the multimedia elements used in Unit 3 related to the SASI framework. Both a static and interactive version of a diagram was created to communicate the investigative cycle, reasoning in each phase at three levels of sophistication, and an indication of productive habits of mind (Figure 1). Two brief PDF documents described the framework and how to apply it to task design. In a video, the instructor illustrated the framework using student work from research, and other video featured expert discussions and interviews, including one of the experts illustrating the development of the concept of mean across levels of sophistication. The participants could also engage in a simulation task and watch two animated illustrations of students' work that highlighted how students approach an investigation using different levels of statistical sophistication. Multimedia elements and design principles used in 10 resources in Unit 3 are described in Table 1.

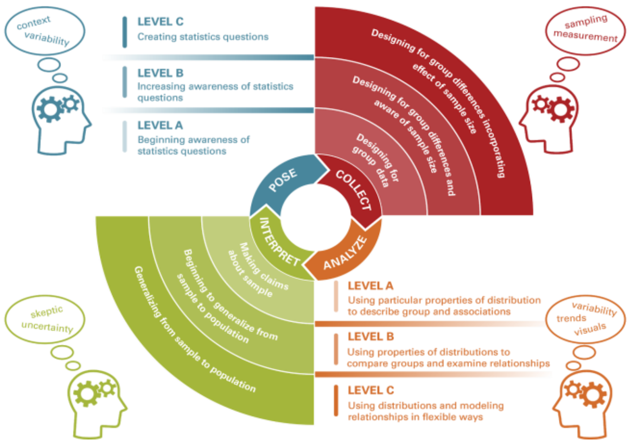

Figure 1. Framework for supporting students' approaches to statistical investigations

OVERALL ENROLLMENT AND ENGAGEMENT TRENDS

In Spring 2015, the first version of the course was offered with 797 enrollees. After the first run, the course was dramatically revised based on feedback and rewritten to be offered in a different course platform. Since Fall 2015, the course content has been relatively stable, with minor edits and updates, and has been offered six different times with a total of 2525 enrollees from all 50 states and 84 countries. The vast majority (61.4%) consider themselves classroom teachers (K-12 or college) and 74.4% have a master's degree or higher. In every run of the course, it was active for about 10-14 weeks, and after that time, the course was archived, but enrollees were always allowed to log into the course and view materials. Thus, the course site becomes a place they can return to continue their learning beyond the official end date, and they may even log on for the first time after the course is finished. In Fall 2015, once the course began, each week a new unit opened, and all others remained opened. Starting in Spring 2016, when the course opened, all units were available so participants could go at a quicker pace. We saw very little evidence of participants skipping units, as participants tended to traverse materials linearly. In each offering, weekly or bi-weekly emails were sent by the instructor to remind participants of course activities and stay in touch. Not surprisingly, this often prompted participants to return to the course.

Table 1. Multimedia resources for participants to learn SASI framework

Title with link to server or YouTube (not within course)	Multimedia and Online Learning Connections	MOOC-Ed Design Principles
Resources accessed through the course library resource database		
Describing the SASI framework	text with diagrams and color coordinated tables. Text integrated into diagram (Mayer & Moreno, 2003)	Job-connected
Illustrating the SASI framework	"talking head" video (12:32 min) with diagrams, animated titles, interspersed with slides with voice overlay showing instructor passion (Mayer & Moreno, 2003; Guo, et al., 2014, Hew, 2014)	Job-connected
Interactive Diagram of SASI framework	webpage with framework diagram and pop-up descriptions of different aspects of the framework (Mayer & Moreno, 2003)	Self-directed (alternative visual for learning)
Considerations for design and implementation of statistical tasks	text with tables that applies SASI framework to task design (Mayer & Moreno, 2003)	Job-connected
Resources accessed through video embedded on a course page		
Expert Panel discussion on task design	video (18:32 min) with instructor and 3 experts having discussion. (Guo, et al., 2014, Hew, 2014)	Multiple voices Job-connected
Expert interview on development of GAISE	brief video (7:06 min) interview between instructor and expert (Guo et al., 2014)	Multiple voices
Expert Interview on developing the concept of mean across levels	video (22:07 min) instructor interviewing expert with interspersed slides (Guo et al., 2014)	Multiple voices Job-connected
Dive into Data with Schoolopoly task and peer discussion (only available within course)	text and embedded simulation applet to decide die fairness provides active learning opportunity (Hew, 2014)	Self-directed Job-connected Peer-supported
Working with a dynamic simulation tool (to explore Schoolopoly)	brief video (4:24 min) with animated depiction of students working on task with real narrator and student voices, and images and video of computer work (Guo et al., 2014, Lassar & Toloza, 2017)	Multiple voices Job-connected
Multiple levels of sophistication (with Schoolopoly)	brief video (5:09 min) with animated depiction of teacher introducing task and three student pairs working with computer images or written work (voices automated) (Guo et al., 2014, Lassar & Toloza, 2017)	Multiple voices Job-connected

Of those that registered from Fall 2015-Fall 2017, only 1733 ever accessed any material in the course (68.6%), in either orientation or in any unit. This is 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 that accessed each unit continued to decrease. Of the participants that showed up in orientation (1436), 25.3% accessed the final unit; however, of those that began Unit 1, 35.5% of them accessed material in Unit 5. This completion rate of 35.5% aligns with Perna et al.'s (2014) suggestion 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. Peer-supported active engagement occurred through discussions among participants and course facilitators. Across the six sections, 2164 discussion threads containing 6381 posts made by 959 participants. There was an average of 6.6 posts per forum participant, though this is a skewed distribution, with some participants posting 30-50 times.

HOW DESIGN IMPACTED EXPERIENCES, PERSPECTIVES AND PRACTICES

An in-depth study of the click data logs is not possible within this paper. However, across the six sections of the TSDI course, 535 participants viewed at least one of the resources stored in the library resource database, which included the Illustrating the SASI Framework video (see Table 1), while slightly less (437) participants engaged in watching at least one of the embedded videos. This is not surprising since the resources stored in the library resources database were the ones in the "Engage with Essentials" section of the unit, while the others were within sections participants may perceive as less important (Learn from Experts, and Investigate and Discuss).

A prior study by Lee, Lovett, and Mojica (2017) focused on the discussion posts made by Fall 2015 teacher participants. We found that the SASI framework, expert video discussions, and videos of students engaged in statistics acted as a major trigger for changing the perspectives of these teachers to include a more robust vision of statistical thinking and teaching strategies for engaging learners in statistics investigations. Looking at the Unit 3 discussion forum and end-of-unit 3 survey, across the six sections of TSDI, participants often talked about how they learned from different multimedia resources related to the SASI framework. Frequently mentioned were the diagram, videos with experts (panel discussion and development of concept of mean), and animated videos of students' work on the simulation task. In each of the following quotes, not only does a participant mention a specific resource, but they provide hints as to how the resource impacted their understanding and application of the SASI framework.

- "From the second video [Multiple levels of sophistication] it is apparent that each group of students investigating whether the die was fair or biased were at different levels of the SASI framework. The ways in which each group collected and analyzed data and interpreted the results indicated their levels of statistical sophistication."
- "I like the SASI handouts [Describing the SASI framework] and graphs [diagram in PDF and interactive diagram]. I realized I do little on posing questions and data collection. I spend most of the semester on analyze and interpret. I have the framework posted right next to my desk now. I think about how to modify how I teach everyday."
- "I loved the video of Chris and Hollylynne talking about the mean [Developing the concept of mean]. It is helping me to get a big picture idea of the curriculum."
- "The SASI framework and example of statistical tasks [Dive into Data] were very useful to design, initiate statistical inquiry in classrooms. The SASI framework helped in becoming more objective and observant in what is going [on] in the classroom, where each group/child is heading and what are gap areas to be worked upon."

Furthermore, from examining responses to "what was the most valuable aspect of this course?" from the end-of-course survey in Unit 5, we collapsed the most commonly referred to learning experiences into the following eight categories, in decreasing frequency:

- access to resources, technology tools, websites, and lesson plans;
- learning from videos of expert panel discussions;
- learning from videos of students and teachers work in classrooms;
- introduction to the SASI framework;
- focus on improving questioning, exploration, engaging students, and active learning;
- engaging in discussions with colleagues;
- appreciation for flexibility and learning at own pace; and,
- being grateful for opportunity and inspired to learn more.

CONCLUSION

The creation of different multimedia seems to be effective in creating memorable and impactful learning experiences for participants. Specifically, use of two different types of videos (expert discussions and students' work on statistics) and presentation of the SASI framework (supported by multimedia) are highly valued. The use of both real videos of students' work in classrooms as well as stop-animation videos (Laaser & Toloza, 2017) seems to be successful in assisting participants in seeing the potential of students' learning if they would enact the pedagogical approaches presented in the course. Many of our designs of multimedia elements of the course are aligned with suggestions from others (e.g., Mayer & Moyer, 2003; Guo et al., 2014). Results from this course specifically designed for educators align with results and suggestions by others on effective MOOCs in other disciplines (e.g., Hew, 2014, Jordan, 2015). While not all enrollees in TSDI completed all units, the learning opportunities presented in the first few units have the potential to help educators consider new approaches to teaching statistics.

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