

## DEVELOPING E-MODULES TO SUPPORT PRESERVICE MATHEMATICS TEACHERS' STATISTICAL THINKING

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*High quality materials related to statistics content and pedagogy are needed for secondary mathematics teacher education. This paper will describe the design principles utilized by a multi-institutional team to develop online modules for preservice teachers focused on statistical thinking and tools for teaching statistical inquiry. Design principles that guided creation and development will be shared, including: 1) use of free and accessible tools, 2) connection to classroom practice, and 3) access and delivery online. The project's role in further developments to CODAP, a free Common Online Data Analysis Platform, will be highlighted. Results of a pilot test implementing the first module will be shared.*

### INTRODUCTION

With additional expectations for students to learn statistical concepts at the secondary level, the demands to enhance teachers' knowledge and skills related to statistics has also increased (Conference Board of Mathematical Sciences, 2012; Franklin et al., 2015). However, new teachers report that they do not feel as prepared to teach statistics in contrast to other mathematical strands. In a recent study, Lovett and Lee (2017) asked 84 preservice secondary mathematics teachers (PSMTs) to rank five content areas (algebra, geometry, advanced algebra/pre-calculus, statistics, and calculus) according to how they were most or least prepared to teach. More than 60% of the PSMTs named statistics as the area they were least prepared to teach. This result suggests that there is a critical need to prepare teachers to teach statistical content.

Preparing PSMTs to teach statistics can look different in different teacher education programs, but many PSMTs in Lovett and Lee's (2017) study reported very few opportunities to learn statistics and pedagogical strategies for teaching statistics. Consequently, there is an important need for curriculum materials to build PSMTs' statistical knowledge for teaching (Groth, 2013) and pedagogical practices for teaching statistics. The *Enhancing Statistics Teacher Education through E-Modules* (ESTEEM) project seeks to address the needs described above through iterative design, development, implementation, evaluation, and revision cycles to create freely available curriculum materials for statistics teacher education packaged into modules. This multi-institutional collaboration has thus far resulted in the creation of online resources for preservice statistics teacher education, the design of modules using these resources, and the initial implementation of our first module in undergraduate teacher education programs. This Foundation Module (available at <http://hirise.fi.ncsu.edu/projects/esteem/>) was released in February 2018 and will be a prerequisite for other forthcoming modules. The Foundation Module (15-18 hours of instructional material) focuses on considering differences between mathematics and statistics, pedagogical considerations regarding tasks and tools used to teach statistics, and ways to support students' engagement in statistical investigations. Additional modules under development focus on big ideas taught at the secondary level that are difficult to teach, such as statistical association and inference.

In this paper, we describe several design principles that guide development of ESTEEM modules. The modules are intended to be delivered in ways that can be easily incorporated into online platforms. Thus, we have design principles *for content* and *for delivery*. We also provide a few examples from our pilot test of the Foundational Module in Fall 2017.

### DESIGN PRINCIPLES FOR CONTENT

#### *Use of Free and Accessible Tools for Data Investigation*

PSMTs need to experience statistical investigations of data with technological tools that will be accessible to them in their future classrooms. The ESTEEM modules utilize accessible,

web-based tools, such as the Common Online Data Analysis Platform (CODAP, 2018) and other free web-based applets and tools that support exploration of statistical concepts and provide authentic experiences of investigating data. These tools also serve to stimulate students' interest in data through investigation of their own statistical questions. The accessibility of these tools in K-12 schools is important; in contrast, many earlier data analysis software tools used in teacher education required the user to download the software and pay for installation.

CODAP (<http://codap.concord.org>), plays a central role in the ESTEEM materials, as Bill Finzer, lead developer of CODAP, participates as a co-Principal Investigator on the ESTEEM project. CODAP's mission is "to make data literacy accessible for *all* students" (Concord Consortium, 2018). It is an open source, HTML5 web application, which has a design based on years of experience of working with *Fathom* and *TinkerPlots* and informed by research on student learning of concepts in data analysis and statistics. One strength of CODAP is its data visualization capabilities. It permits a user to easily create data displays, including dot plots, box plots, scatterplots, bar graphs, segmented bar graphs and binned dot plots (data visualization of a two-way table that can also show frequencies and percents). Through the use of color, users can explore up to three variables in a single data representation, and the representations are dynamically linked, allowing the user to examine comparisons between two data representations (such as a table and a graph). A unique aspect of CODAP is that it allows for exploration of data that is structured hierarchically. The ESTEEM project has been influential in furthering development of CODAP, such as producing new graphing capabilities for categorical data and creating a sampler tool to simulate data drawn from a mixer or spinner model and the collection of random samples from a data set.

*Investigation of Engaging, Real, Larger, and Messy Data Sets*

In creating data sets to include in ESTEEM materials, we prioritized real data we believe will appeal to PSMTs and their students. By using real data, the data exploration becomes a more authentic experience for PSMTs. We also chose data sets with a larger number of cases than is typically used in schools and included multiple variables (quantitative and categorical). Data sets in which the data is somewhat "messy," such as having missing data, were also purposefully chosen.

One data set created by the ESTEEM project and included in the Foundation Module is about 157 roller coasters in the United States. The data set includes demographic information on the roller coasters (e.g., name, park, state), three categorical variables (e.g., whether it inverts or not), and seven quantitative variables (e.g., greatest height). Figure 1 shows an exploration in CODAP comparing the top speed of the roller coasters disaggregated by the three age groups (older, recent, and newest), with coasters colored by whether they are wooden or steel. The graphical display shows a box plot with a dot plot for each of the age groups, and the blue vertical lines represent the means of each age group.



Figure 1. Investigation of roller coaster data set in CODAP.

### *Connection to Classroom Practice through Videos*

Video provides an opportunity to connect PSMTs to classroom practice and permits online learners with a medium for learning that transcends static reading of course content. Although many projects have resulted in high-quality video-based materials for mathematics teacher education (e.g., Philipp, Cabral, & Schappelle, 2011; Seago, Mumme, & Branca, 2004), few videos exist of middle and high school students engaged in learning and reasoning about statistics. One strength of the ESTEEM modules is the utilization of a diverse set of videos.

In the Foundation Module, PSMTs view fourteen videos. One video shows an expert panel of statisticians and statistics educators discussing the criteria they use to select data sets for use with students. Some videos feature a single narrator describing key features in statistics education, including one where the narrator describes the levels of student thinking when conducting a statistical investigation. Other videos are interviews with teachers or teacher leaders who discuss tools they use with students and advice for incorporating statistics into the mathematics curriculum. Additional videos show secondary classrooms where students are learning statistics. For example, one video shows how a teacher launches an investigation about roller coasters, and a subsequent video demonstrates how that teacher orchestrated a class discussion based on students' results when investigating variables of interest to them in CODAP. Through use of these videos, the voices of experts, real teachers, and students are foregrounded in teacher education.

In the pilot study, the videos encouraged PSMTs to consider new ideas about statistics. For example, during an expert panel video, one panelist described how students need to be able to 'clean data' prior to analyzing it. This term was new for many PSMTs, and the video provided an opportunity to discuss what this meant and consider how raw data may be problematic to use.

## DESIGN PRINCIPLES FOR DELIVERY

### *Organization & Structure*

All ESTEEM modules have a common structure and are expected to take 15-18 hours for PSMTs to complete. Each module is structured into sections entitled "Read and Watch," "Engage with Data," and "Synthesize and Apply." The "Read and Watch" section is divided into two types of content: "Essential Materials" and "Learn from Practice" videos. The "Essential Materials" include required readings and informative videos, which are followed by a short quiz. The "Learn from Practice" videos may include classroom video or videos of expert panels. The second section, "Engage with Data," provides opportunities for PSMTs to explore data through use of CODAP or other tools. In addition to engaging with data themselves, teachers learn pedagogical strategies for supporting students' engagement with data, such as how to launch a statistics investigation. The third section, "Synthesize and Apply," includes activities, reflections, and discussions for PSMTs to connect ideas from prior sections to applications of practice (e.g., analyzing tasks).

### *Access & Delivery*

One challenge in developing online materials for instruction in higher education is that individual institutions utilize different platforms for online instruction. Learning Management Systems (LMS) are software programs designed for the administration and delivery of educational courses and programs. In the United States, the three most commonly used LMSs are *Moodle*, *BlackBoard*, and *Canvas*. Although these LMSs have the capability to export and import content between one another, the imported content does not always have the same layout or features in a different LMS. As part of our design work, we investigated what features allow for import between LMS, and we designed modules for import into each of these popular LMS. By providing teacher educators with content that is easily accessible and designed for their LMS, we believe teacher educators will be more willing to use the ESTEEM modules. In our pilot test, we imported materials into Moodle and Blackboard and discovered many compatibility issues, which led to the design of better, export and import processes.

By permitting individual instructors to import ESTEEM modules into their own LMS, instructors also have the capability to modify the materials to meet their students' learning needs. The ability to customize online curriculum materials is a benefit over static textbooks, which typically cannot be easily altered to meet their personal context. It also provides capacity for instructors to modify and use ESTEEM modules in various settings, including synchronous and

asynchronous online instruction, hybrid instruction, and face-to-face instruction. We recognize that this flexibility also impacts implementation fidelity—a topic we will examine in the future.

#### *Meaningful Interactions with Other PSMTs through Discussion*

Students learning in an online setting often feel isolated unless the course is structured to promote student discourse. To ensure the PSMTs in online settings are interacting with one another, we incorporated the use of discussion boards in our modules to allow the PSMTs to interact with one another and their instructor. The excerpt below is a PSMT's response to a discussion prompt that asked the PSMTs to compare opportunities provided in the module compared to their own prior learning experiences with statistics:

...After this module, I feel prepared to introduce statistics to students as something fun and exciting, and something that can lead to many discoveries. Listening to all of the professors talk about teaching statistics made me feel much more at ease and made me start thinking about how I would incorporate statistics into my own teaching. I liked the idea of having students "unpack the data" when dealing with a real-world data set. This means the students are the one asking and answering questions such as, how was this data collected and analyzed, and were there any relationships between variables? This would be near impossible without technology...

This excerpt was part of a longer post to which four of her peers replied with ideas building on her sentiments that the module allowed them to view statistics education in a different way.

#### CONCLUSION

Engaging in design and development across institutions with multiple authors demands a shared set of design principles for content. If our project is going to succeed in giving access to high quality materials to more faculty and their PSMTs, our design principles for delivery will likely continue to evolve as we study how easily and with what fidelity instructors use ESTEEM modules. The ESTEEM project is addressing the need for development of resources for statistics teacher education at the secondary level, and we have made these guiding design principles in an effort to make our curriculum materials effective and useful. In 2018-2019, we will track use of the Foundational Module at 15 university sites to study both how PSMTs engage with materials and how teacher educators integrate the module into their teacher preparation programs. These findings will inform revisions and provide input for development of future content-specific modules.

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