ABSTRACT

AKOĞLU, KEMAL. Blending Online Coursework and Small Learning Communities to Examine Professional Growth in Teaching Statistics: A Phenomenological Case Study. (Under the direction of Dr. Hollylynne Lee).

The Teaching Statistics Through Data Investigations professional development course is a Massive Open Online Course (MOOC) designed to strengthen participants' ability to use a statistical investigation cycle to teach statistics and help students explore data using technology tools and make evidence-based claims. The case of interest for this research are 63 MOOC participants who also participated in one of nine professional learning teams (PLTs) during 2016-2017. This is a phenomenological study describing and explaining the lived experiences of 63 PLT participants' MOOC and PLT engagements, and the impacts of those lived experiences in participants' perspectives about and practices in teaching statistics. The hypothesis is that a blended professional development experience could impact practices and perspectives related to teaching statistics. PLTs met several times, either face-to-face or virtually, to discuss their course experiences and teaching practices. This study will describe the phenomena of simultaneously participating in MOOC and PLT, and report results on how this blended professional development experience impacted participants' professional growth in teaching statistics.

Understanding how such a blended professional development experience can impact professional growth in teaching statistics is important, so that perhaps others can implement such a model to make more wide-scale changes in teaching statistics.

Data was collected from sources of PLT participants' MOOC and PLT engagements, such as MOOC forum discussions, MOOC surveys, PLT meeting summaries, PLT surveys, and PLT interviews. Most of the data collected and analyzed for this research was qualitative and coded using both a priori codes and open coding to identify the strongest shared lived

experiences and impacts on practice. Quantitative data was analyzed using statistical tests to measure significance in growth of confidence to teach statistics, and descriptive statistics with data logs and end-of-course surveys used to confirm or refute qualitative data-based claims.

Participants' lived experiences in the MOOC and PLT were found to be related to essential impacts in teachers' perspectives about and practices in teaching statistics. For example, by learning about and applying SASI framework, learning about and engaging with real and messy data, learning about and engaging with technology, sharing about personal practices, and encouraging each other to progress, participants gained confidence in teaching statistics. Also, by observing practices from videos, sharing about personal practices, and unpacking various MOOC materials during their PLT meetings, participants developed a commitment to continue learning skills to teach statistics.

Results from the study indicate that a blended approach to professional development is an effective way to increase statistics educators' confidence to teach statistics; improve their knowledge, beliefs, and perspectives about statistics education; and to help them better understand students' approaches to statistical investigations. Results also suggest a positive impact in teaching practices of statistics teachers, however, there is not enough direct evidence to strongly support this claim.

Blending Online Coursework and Small Learning Communities to Examine Professional Growth in Teaching Statistics: A Phenomenological Case Study

by
Kemal Akoglu

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APPROVED BY:

_____   _____
Dr. Hollylynne Lee   Dr. Allison McCulloch
Committee Chair

_____   _____
Dr. Roger Azevedo   Dr. Molly Fenn

DEDICATION

For Tülay, Erdem and Barış

BIOGRAPHY

Kemal Akoğlu was born and raised in Antakya, Turkey. He graduated from Ankara University with a BS in Mathematics in February 2008. Kemal taught mathematics for middle school and high school students until he moved to the U.S. in July 2009. Kemal has been interested in sociology and literature since his high school years. He enrolled in the Applied Sociology master's program at Clemson University in January 2010. After a successful year of coursework and a graduate research assistant (GRA) job, Kemal took a leave of absence from the program and moved to Raleigh, North Carolina.

In the fall of 2012, with the encouragement and support of his wife, Dr. Tülay Ayyıldız Akoğlu, and his later advisor, Dr. Hollylynne Lee, he applied to the master's program in Mathematics Education at North Carolina State University (NCSU). During his master's study, he worked as a GRA for the Preparing to Teach Mathematics with Technology (PTMT) research project. He accomplished his coursework in this program in Spring 2014 and earned his master's degree in August 2014. His thesis focused on cognitive issues in the teaching and learning of conditional probability and the methods used to overcome those issues. His thesis advisor was Dr. Hollylynne Lee.

After graduating from his master's program, he began his doctoral studies at NCSU beginning in the fall of 2014 to continue his career in mathematics education. During his doctoral studies, he worked as a graduate research assistant or teaching assistant (TA) for several projects and courses at the university, including the courses EMS 472 (Teaching Mathematics Topics in Senior High School), EMS/ST 519 (Teaching and Learning of Statistical Thinking), and the projects Preparing to Teach Mathematics with Technology (PTMT), Gateways to Algebraic Motivation, Engagement, and Success (GAMES), and the networked MOOC-Ed for Teaching

Statistics through Data Investigations (TSDI) projects. Kemal finished his coursework and preliminary exams during the summer of 2016. He started working on his dissertation during fall 2016, under the direction of Dr. Hollylynne Lee, his doctoral advisor and mentor. He finished writing his dissertation in November 2017.

After obtaining his doctoral degree, Kemal plans to pursue a career in academia in Turkey, where he currently lives with his wife and two sons.

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CHAPTER 1: INTRODUCTION

Introduction and Outline

Teaching statistics is an essential subject because almost every field of research and practice needs and uses data; such as medical sciences, engineering, economics, sociology, physics, and even sports sciences. In a world with an emergent need for data literacy, understanding the teaching of statistics has recently become very important and popular among education researchers (Cobb, Wood, Yackel, & McNeal, 1992; Garfield, 1993, 1995; Everson, Zieffler & Garfield, 2008; Batanero, Burrill & Reading, 2011; Burrill & Biehler, 2011). The rapid development of educational technologies has created opportunities for research about statistics itself and about statistics education.

Several reports that include guidelines on how to teach statistics (to enhance students' learning and teachers' confidence and knowledge in statistics) have been published. From the American Statistical Association, the Guidelines for Assessment and Instruction in Statistics Education (GAISE) reports for K-12 (Franklin et al., 2007) and College (ASA GAISE working group, 2005, 2016) have provided new visions and frameworks for teaching statistics, and the Statistical Education of Teachers (SET) report (Bargagliotti & Franklin, 2015)) provided guidance for what statistics teachers should know. According to the SET report, there should be changes and developments in the ways teachers teach statistics and in the ways we prepare teachers to teach statistics.

In their seminal paper from a study of how statisticians think and work, Wild and Pfannkuch (1999) claimed that doing statistics involves a process of data investigations and specific ways of thinking about data. Teachers need to be knowledgeable about this method to enhance students' learning (Franklin et al., 2007). The GAISE K-12 report represented the work

of Wild, Pfannkuch, and others to organize teaching statistics as phases in a statistical investigative cycle: posing a question, collecting data, analyzing data, and interpreting results.

In a major effort to educate teachers in 2015, Hollylynne Lee and colleagues launched the Teaching Statistics through Data Investigations (TSDI) massive open online course (MOOC) to prepare middle school, high school, and postsecondary teachers in pedagogy for teaching statistics (see http://go.ncsu.edu/tsdi). The TSDI MOOC is part of a larger effort at the Friday Institute for Educational Innovation at North Carolina State University to create and implement MOOCs designed specifically for educators, to use design principles based on effective professional development and are specifically targeted at better preparing educators for the current challenges in K-12 education (Kleiman, Wolfe & Frye, 2013).

The TSDI MOOC-Ed allows participants to learn together with educators from other schools, to use a statistical investigation cycle for teaching statistics, and to enhance their students' abilities to explore data for making evidence-based claims. Since 2015, the course has been offered every semester with over 3,500 participants (teachers, students, researchers, etc.) from all 50 U.S. states, and at least 84 countries.

With a small grant funded by the American Statistical Association, Hollylynne Lee aimed to support local changes in statistics teaching and collaborative learning among teachers by supporting professional learning teams among TSDI MOOC-Ed participants during fall 2016 and spring 2017. In those small teams, groups of participants were supposed to meet several times and share their learning and experiences in the course, as well as their statistics teaching practices. The plan was to pursue a blended approach to professional development among teachers of statistics.

The hypothesis guiding this research study is that the use of blended professional development models (that combine an online course with local professional teams) could provide the potential benefit of having local teams complete a course together and commit to making pedagogical changes in their classrooms.

Background

Even though the GAISE K-12 framework was published in 2007, and the Common Core State Standards (2010) include heavier emphasis on statistics in middle and high school, evidence suggests that teachers approach statistics as another set of computations and graph-making skills they need to teach, (Cobb & Moore, 1997; Rossman, Chance, Medina & Obispo, 2006; Batanero, Burrill & Reading, 2011) mostly void of context (i.e., data without meaning). Further, Lovett and Lee (2017) have shown that preservice teachers are not being prepared to understand the content they are expected to teach in high school, nor are they very confident in their preparedness to teach statistics. Statistical habits of mind are at the core of what teachers are to learn in the TSDI MOOC. Habits of mind are developed when a person approaches similar situations in similar ways so that a more general heuristic is accumulated over time (Lee & Tran, 2015a).

Lee and Tran (2015b) proposed the Students' Approaches to Statistical Investigations (SASI) framework to help statistics teachers support students. The SASI framework builds on the GAISE K-12 framework (Franklin et al., 2007) and is grounded within four phases of statistical investigation (pose a question, collect data, analyze data, interpret results). Statistical habits of mind are intermixed throughout the phases and describe growth in levels of statistical sophistication. The TSDI course introduces participants to this framework and builds opportunities for participants to learn how to apply these ideas in task design, engage in data

investigations themselves, and analyze students' work. Research on teachers' change (change in their knowledge, beliefs, perspectives, practices) in teaching statistics through professional development requires a broader look at teacher education literature. Clarke and Hollingsworth (1994, 2002) explains teachers' professional development and recommends key considerations for in-service and preservice teacher training programs. The authors describe six perspectives about teacher change: (1) changes as training; (2) change as adaptation; (3) change as personal development; (4) change as local reform; (5) change as systemic restructuring; and (6) change as growth or learning. The authors state that those perspectives are not mutually exclusive, and they are interrelated. However, most professional developments align with the change as growth or learning perspective. In this perspective, change is identified with learning, and it is regarded as a natural and expected component of the professional activity of teachers and schools (Avineri, 2016) and, historically, "teacher change has been directly linked with planned professional development activities" (Clarke & Hollingsworth, 2002, p. 948). A model to explain the process of teacher change was developed by an international group of researchers (Teacher Professional Growth Consortium, 1994), as the Interconnected Model of Teacher Professional Growth. The Interconnected Model of Teacher Professional Growth suggests that professional growth (change) occurs through the mediating processes of reflection and enactment in four domains that encompass the teacher. These domains are (1) the personal domain (teachers' knowledge, beliefs, and attitudes); (2) the domain of process (teachers' professional experimentation); (3) the domain of consequence (salient outcomes of professional development); and, (4) the external domain (sources of information, stimulus, and support). The Interconnected Model of Professional Growth will be used as the model for explaining teachers' change or professional growth in this study.

Statement of the Study and Research Questions

The purpose of this study is to identify the effectiveness of a blended professional development effort to support the professional growth of teachers in their statistics teaching practices. Using a professional learning community, and specifically a community of practice (CoP) approach (Wenger, 2001) to professional development, nine professional learning teams (PLT) and 63 members participated in the research, along with the 804 other MOOC participants. The integration of the community of practice approach to professional development was expected to increase participants' understanding of the investigative cycle, statistical habits of mind, levels of sophistication, and to help them meet the course objectives, and thus, to demonstrate professional growth in their teaching practices.

The following questions guide this research:

1. In what ways does participation in a MOOC and in a PLT focused on teaching statistics impact teachers' professional growth in:

    a. Perspectives and beliefs about teaching statistics;

    b. Confidence to teach statistics;

    c. Understanding how to support students' approaches to statistical investigations?

2. How does participation in a MOOC and PLT impact the nature of planned or self-reported uses of various instructional strategies for supporting students' approaches to statistical investigations?

The following section is a literature review about the following main topics: (1) teaching statistics; (2) teachers' professional development; (3) theoretical perspectives and framework for examining teachers' professional growth.

After the relevant research is synthesized and a theoretical framework is presented and discussed, the methodology of collecting and analyzing the data is explained. The results are organized in two chapters, and a final discussion appears in Chapter 6.

Definitions of the key terms

The following terms are used throughout this study with the following definitions.

Community of practice: A group of people that learns with communal participation.

Levels of statistical sophistication: These provide guidance of reasonable expectations for learners, and thus could be used to develop tasks, instructions, and assessments (Level A, Level B, Level C).

MOOC: Massive Open Online Course is a free course offered online to a wide range of participants that want to learn about a specific subject.

MOOC-Ed participant: A person who participates in a MOOC.

PLT: Professional learning team is a group of educators who meet regularly to discuss their learning in the MOOC and their experiences in school.

PLT leader: The person who forms and leads a PLT.

PLT member: A person who participates as part of a PLT.

Statistical habit of mind: Within the context of statistics, this is developed when a person approaches similar situations in similar ways so that a more general heuristic is accumulated over time.

Statistical investigative cycle: Four phases of statistical investigations (pose a question, collect data, analyze data, interpret results)

Teacher of statistics: A person who teaches students statistics in a classroom setting.

Teacher's professional growth: Inevitable and continuing process of learning by teachers.

The following definitions are related to the framework guiding this study.

Domain of practice: The domain of application and experimentation.

Engagement: The action of engaging or being engaged.

External domain: Sources of information, stimulus, and support.

Enactment: The mechanism by which someone puts a new idea, belief, or a practice into action.

Impact: The effect or influence of one person, thing, or action on another.

Lived experience: A subject's experiences, choices, and options and how those factors influence that subject's perception of things.

Personal domain: The domain of knowledge, beliefs, and attitudes.

Reflection: Active, persistent, and careful consideration.

Self-report: Data sources where subjects reflect on their experiences, beliefs, or actions within a phenomenon and report those beliefs, experiences, or actions themselves.

CHAPTER 2: LITERATURE REVIEW

This literature review provides an overview about teaching statistics, including trends, issues, history, and research-based recommendations for teaching statistics. Literature is also synthesized concerning online learning settings, MOOCs, and how these are aligned with learning opportunities, especially with active-situated learning theory (Lave & Wenger, 1991) which is discussed in the related section of the literature review.

A literature synthesis about supporting the role of professional development in teachers of statistics' professional growth is also provided.

The final part of this chapter cumulates in a framework (or model) to guide this research study on the role of the TSDI MOOC and PLTs in teachers of statistics' professional growth both in their personal beliefs and perspectives, and also in their professional practices.

Teaching Statistics

Background

According to Jolliffe (1998), teaching statistics became viable in universities and schools only after World War II. Since then, statistics has become widely recognized as a discipline (with differences from mathematics), and thus an academic emphasis on better understanding aspects of teaching statistics started to form. The first international institution for statistics, International Statistics Institute (ISI), was set up in 1948; its first round-table meeting was conducted in 1968; the first specific journal about statistics education (*Teaching Statistics*) was published in 1979; the first international conference, International Conference on Teaching Statistics (ICOTS), was held in 1982. Only since then, the interest (observable interest) about teaching statistics has really grown. Until 1982, many instructional strategies that were suggested

for teaching mathematics were equally applied to teaching statistics (Joliffe, 1998). And though

many points are common between two, there are some essential differences, which mostly come

from the differences between mathematics and statistics as two different disciplines. Despite

these differences, there is not a separate position for K-12 statistics teachers; mathematics

teachers are expected to teach statistics within the mathematics curriculum. Actually, it is

difficult to use the term "statistics teachers," because in the U.S. (and in many other developed

countries), there is no such separate position in schools, or a separate discipline in education

departments' undergraduate programs. The situation varies at the university level. Some

universities (e.g. University of Florida, University of Minnesota, Penn State University Eberly)

have a statistics education focus at the graduate level, while others integrate mathematics and

statistics education (e.g., North Carolina State University). Also, a few universities have

initiatives for a focus on statistics education in their undergraduate program (e.g. University of

Georgia, North Carolina State University, Texas A&M University). Community colleges and K-

12 institutions still treat statistics as a branch of mathematics that is typically taught by

instructors who also teach other mathematics courses. Differentiating between mathematics and

statistics has been an ongoing issue; they consist of several differing essentials and

characteristics. What are the differences between statistics and mathematics?

Mathematics as a field heavily deals with deterministic situations, proofs, and problems;

statistics, however, exists in a world of uncertainties and deals with probabilistic situations.

Statistics was considered as a sub-field of mathematics, because probability was formalized

before statistics, and only the theoretical probability approach, which uses mathematical

calculations and problem-solving strategies, was on the stage for a long time. By the time

different approaches to probability emerged (frequentist and subjective approaches to

probability), probability needed a different set of thinking, teaching, and learning characteristics, and statistics, which referred to working with the key characteristics, such as data, data patterns, variation, distribution, and inference, had been formed. Statistics was mainly about data within context (Makar & Rubin, 2009). While context is essential in statistics teaching and learning, in mathematics it is sometimes ignored, though, mathematical modeling certainly deals with contextual issues of how to use mathematics to model real world phenomena. Some other characteristics between statistics and mathematical modeling could also be presented, such as their inquiry-based nature. According to Callingham and Watson (2011), statistics is known as cross curricular, mathematics is not; statistics is practical, mathematics is abstract; statistics encourages critical thinking, mathematics is more mechanical when they are compared. Statistics is considered a bridging discipline between mathematics and science (Garfield & Ben-Zvi, 2008). Both social and physical sciences use statistics in their empirical research, thus, the need to teach K-12 students how to reason, collect, and analyze data had emerged. Statistical concepts can be best taught in real world contexts, where mathematics does not have such a requirement. Again, the role of context is important in statistics and in statistics education at all levels, thus it needs attention when strategies are discussed for training teachers of statistics.

Pfannkuch and Ben-Zvi (2011) discussed the relationships between statistical knowledge and contextual knowledge. The authors discussed the distinctions between data contexts (i.e., where the data arises) and learning experience contexts. According to the authors, data contexts usually focus on a social situation or real-world issue. On the other hand, learning experience context contains learners' background and physical-social environment they live in. Learning experience could be similar (or the same) between mathematics and statistics, but data contexts are considerably different between the two disciplines. According to Pfannkuch (2011), in

mathematics, context could be described as a vehicle that leads to the strongest generalization; thus, researchers usually drop it before they reach that generalization. On the other hand, in statistics, the context is at the center of the learning experience and it is relevant to the whole learning process.

Researchers in the field of mathematics and statistics education (Moore, 1998; Gal, 2002; Lee & Hollebrands, 2011; Biehler, Ben-Zvi, Bakker, & Makar, 2012; Lee & Strangl, 2015) agreed that statistics is a general intellectual method, and it needs to be incorporated into school education. Pfannkuch (2008) discussed that a teacher of statistics must realize that teaching statistics is not a branch of mathematics, but it is teaching a discipline with its own independent intellectual method, and thus it should be taught by considering its own needs and characteristics. An important issue is that most students and adults do not readily think statistically about important issues which influence their lives (Ben-Zvi & Garfield, 2008). As argued by Gal (2002), understanding, interpreting, and reacting to real-world situations which contain statistical elements requires more than learning statistical content. Instead, those skills should be built on interactions between knowledge bases and supporting dispositions. These skills should be incorporated with statistical knowledge, mathematical knowledge, and common world knowledge. However, traditional instructional approaches to teaching statistics mostly focused on mathematical procedures which are insufficient for reasoning statistically (Biehler et al., 2012). It is vital to learn the nature of statistical thinking for statistics teaching, and to realize the differences between mathematical and statistical reasoning.

The major reports endorsed by the American Statistical Association, including the Guidelines for Assessment and Instruction in Statistics Education (GAISE) (Franklin et al, 2007), GAISE College Report (ASA GAISE working group, 2016) and Statistical Education of Teachers

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reports (Franklin et al., 2015), suggest that conceptual understanding of statistical ideas is essential for teaching statistics and statistical thinking needs to be emphasized for teachers of statistics.

The next section will attempt to describe the nature of statistical thinking and the distinguishing characteristics of statistics, which require us to consider it as a separate discipline, rather than a sub-section of mathematics. Then, the review will cover teachers' knowledge, beliefs, and practices about statistics. Finally, as an essential part of statistical literacy and statistics education, the role of technology will be discussed.

Nature of Statistical Thinking

"Statistical thinking will one day be as necessary for efficient citizenship as the ability to read and write" H. G. Wells (quoted in Snee, 1990, p. 117).

To describe the nature of statistical thinking, first we need to distinguish statistical literacy, statistical reasoning, and statistical thinking. According to Garfield, delMas, and Chance (2003), statistical literacy includes basic and important skills that may be used in understanding statistical information or research results: being able to organize data, construct and display tables, and work with different data representations. Statistical literacy also includes an understanding of concepts, vocabulary, and symbols, and includes an understanding of probability as a measure of uncertainty (Ben-Zvi & Garfield, 2004). Statistical reasoning, on the other hand, could be defined as the way we reason with statistical ideas and make sense of statistical knowledge. It involves being able to make interpretations based on data. Statistical reasoning could also involve interconnecting the statistical concepts, and it could combine ideas about data and chance. Finally, statistical thinking is about understanding why and how statistical investigations are conducted. It is the understanding of big ideas behind statistical investigations, which include the pervasive nature of variation and how to use appropriate methods of data analysis. Statistical thinking involves the understanding of

sampling, making inferences from samples to populations, and why experiments are needed for establishing causation. It also involves an understanding of using models for simulating random situations, producing data to estimate probabilities, and how inferential tools could be used to help investigation. Statistical thinking requires understanding and utilizing the context of a statistical problem to form investigations and draw conclusions from the entire investigation process. Statistical thinkers must be critical about the results and evaluate those results drawn from an investigation (Ben-Zvi & Garfield, 2004; Wild & Pfannkuch, 1999).

Addressing Hacking (1975), Pfannkuch and Wild (2004) stated that two significant shifts in thinking took place during the Renaissance, which later allowed statistical thinking to become a theory. Those shifts were: (i) "the concept of knowledge shifted from an absolute truth toward knowledge based on opinion, resulting in the thinking shifting toward a probabilistic perspective, and, (ii) the nature of evidence shifted away from the pronouncements of those in authority and toward making inferences from observations, resulting in the thinking shifting toward reasoning from data" (p. 21). Those two shifts led to a new paradigm for viewing and learning about the real world. Tversky and Kahnemann (1974) also focused on statistical thinking and they discovered that it is extraordinarily difficult to be a statistical thinker. Thus, there should be explicit norms and principles to be able to talk about educating people to become statistical thinkers.

According to Pfannkuch and Wild (2004), statistical thinking is a thought process which arises; "(i) during data-based enquiry to solve a practical problem; (ii) during interaction with a data-based argument, and, (iii) during interaction with data-based phenomena within one's operational environment" (p. 42). The authors argue that statistical thinking increasingly became an integral part of various areas of human thought, and it should not be underestimated. Essentially, educators should be aware that the development of statistical thinking is crucial to understand and

operate in today's world and perceive reality. The methods used to teach statistics should be carefully examined and pedagogical best practices should be built. However, there are challenges to develop learners' statistical thinking through teaching statistics. Those challenges are listed as below (retrieved from Pfannkuch & Wild, 2004):

- Raising awareness about the characteristics of statistical thinking, reaching a common consensus on students' understanding of statistical thinking, and developing a common language to describe and communicate it;

- Recognizing statistical thinking in a variety of contexts and situations and be able to explain and justify how and why that type of communication constitutes statistical thinking;

- Developing strategies for teaching that will promote and enhance students' statistical thinking. It will also require mapping out a developmental pathway for statistical thinking across the curriculum and learning about and recognizing the intuitive statistical thinking that is already present in students);

- Implementing teaching and assessment strategies that focus on developing students' statistical thinking.

Arguing that statistical thinking is a complex activity, Wild and Pfannkuch (1999) identified five elements that they believe are fundamental for statistical thinking in an empirical inquiry. Those elements are (i) recognition of the need for data; (ii) transnumeration; (iii) consideration of variation; (iv) reasoning with statistical models; and, (v) integrating statistical and contextual knowledge. Wild and Pfannkuch (1999) also stated that doing statistics involves a process of data investigations, and there are phases in a statistical investigative cycle: problem, plan, data, analysis, and conclusion (PPDAC).

Franklin et al. (2007) proposed a framework for K-12 statistics education. According to the framework, any statistical problem is an investigative process, which they collapsed into four components: formulating a statistical question that can be answered with data, designing a plan to collect appropriate data, analyzing data by selecting appropriate graphical and numerical methods, and interpreting the analysis and relating the interpretation to the original question.

Lee and Tran (2015b) proposed the Students' Approaches to Statistical Investigations (SASI) framework to help teachers of statistics support their students to become better statistical thinkers. SASI framework mainly uses four phases of statistical investigations (pose a question, collect data, analyze data, and interpret results), and statistical habits of mind are intermixed throughout the framework. There are specific habits of mind that are productive for engaging in while doing statistics, according to the authors, and learners and teachers need to develop these statistical habits of mind. Those habits of mind are: "Always consider the context of data; ensure the best measure of an attribute of interest; anticipate, look for, and describe variation; attend to sampling issues; embrace uncertainty, but build confidence in interpretations; use several visual and numerical representations to make sense of data; be a skeptic throughout an investigation" (p. 1).

Also, building from the GAISE K-12 report (Franklin et al., 2007), the SASI framework includes more evidence from research to describe growth in levels of statistical sophistication. These levels, level A to level C, "are meant to provide guidance of reasonable expectations for learners, thus they could be used to develop tasks, instructions, and assessments" (p. 1).

The context of this dissertation is professional development (a massive open online course) specifically designed around these ideas, aimed to prepare teachers of statistics to teach statistics through data investigations.

Teachers' Statistical Reasoning

According to Makar and Confrey (2004), in order to promote statistical reasoning of students, we should better understand and engender teachers' statistical thinking and reasoning. However, research about teachers' understanding of statistical ideas is relatively new. The authors argued that there should be opportunities for teachers "to construct understanding and recognize use of statistical concepts like data and distribution as they appear holistically in the context of conducting purposeful applied statistical investigation with children" (p. 349). There is no question that learning all the statistical content prior to teaching is not possible. Teachers could take the role of learner, which requires both confidence and a willingness to deal with uncertainty. Thus, by attending professional development in which statistics educators whom they work with openly model such an approach, teachers could learn to see this disposition toward teaching and learning (Mickelson & Heaton, 2004). For example, the concept of variation is an important emphasis in statistics and it needs to be obtained early for a teacher teaching statistical reasoning to students. Thus, "teaching of statistics throughout schooling, with an emphasis on distribution and variation, may provide a way to loosen the deterministic stance of teachers, students, and the public toward data and statistics" (Makar & Confrey, 2004, p. 372).

Teachers' knowledge and ways of reasoning play an essential role in teaching statistics. In this section, the research about knowledge of teachers of statistics will be discussed and several frameworks for statistical knowledge of teachers will be presented. In order to present specific frameworks about statistical knowledge of teachers, first the ideas about the general knowledge of teachers will be presented.

In Shulman's seminal work (1986), he presented a framework about teachers' knowledge that included teachers' subject matter knowledge as having three main components: content

knowledge, pedagogical content knowledge, and curricular knowledge. Content knowledge is defined as the amount of a teacher's knowledge and organization. Pedagogical content knowledge "goes beyond the knowledge of subject matter per se to the dimension of subject matter knowledge for teaching" (p. 9). Curricular knowledge refers to the knowledge of different programs and corresponding materials available to teach the relevant content. More recently, Hill, Ball, and Schilling (2008) presented a framework for mathematical knowledge for teaching (MKT) that further parsed pedagogical content knowledge and subject matter knowledge. Godino, Ortiz, Roa, and Wilhelmi (2011) stated that "teachers are not only simple components of the educational system, but teachers' thinking (beliefs, conceptions, and attitudes) is also essential" (p. 271). The authors state that there are two key elements in the didactical analysis of teaching and learning processes, and those are epistemic (mathematical or statistical content) and cognitive (students' learning) elements. According to the authors, mathematics was considered "a human activity arising from people's practices when working with specific problem-solving situations" (p. 274).

Statistics has a specific epistemic nature, as there are specific problems, representations, and procedures for statistical contents. Thus, the human activity arising from people's practices will inevitably be specific to statistics. Citing from Wild and Pfannkuch (1999), the authors describe the main statistical problems as related to the concepts of inference and decision making under uncertainty, which includes random variation and specific practices, such as collecting data, randomization strategies, transnumeration and tabulation, reduction of data, using representations, and using statistical modeling.

Cobb and McClain (2004) proposed six instructional design principles for statistics teaching:

1. Focus on developing central statistical ideas rather than on presenting a set of tools and procedures;

2. Use real and motivating data sets to engage students in making and testing conjectures;

3. Use classroom activities to support the development of students' reasoning;

4. Integrate the use of appropriate technological tools that allow students to test their conjectures, explore and analyze data, and develop their statistical reasoning;

5. Promote classroom discourse that includes statistical arguments and sustained exchanges that focus on significant statistical ideas;

6. Use assessment to learn what students know and to monitor the development of their statistical learning as well as to evaluate instructional plans and progress.

According to Godino et al. (2011), those principles suggested by Cobb and McClain (2004), can be interpreted as an implicit model for didactical knowledge of statistics teachers. For example, the GAISE College report (ASA GAISE College working group, 2016) suggests a direction for introductory statistics courses by presenting the following recommendations:

1. Teach statistical thinking;
    a. Teach statistics as an investigative process of problem-solving and decision-making;
    b. Give students experience with multivariable thinking;

2. Focus on conceptual understanding;

3. Integrate real data with a context and purpose;

4. Foster active learning;

5. Use technology to explore concepts and analyze data;

6. Use assessments to improve and evaluate student learning.

Cobb and McClain's (2004) principles are also used by researchers such as Ben-Zvi and Garfield (2008) to design and teach statistics courses (both for students and prospective mathematics teachers). Teachers of statistics must "develop competence to recognize the statistical objects and processes that intervene in the students' statistical practices, be aware of the norms that support and condition learning, affect, resources and interactions in the classroom" (p. 12). Thus, a critical component of teachers' knowledge for teaching statistics goes beyond their understanding of the content and must attend to their understanding of, and ability to enact in practice, pedagogical practices that are appropriate for statistics.

Teachers' pedagogical statistical knowledge is crucial in explaining the readiness to teach secondary statistics. Franklin et al. (2007) stated that teachers must have pedagogical statistical knowledge to evaluate students' understanding of statistics and to organize ways to develop students' statistical reasoning through their teaching.

According to Callingham, Watson, and Burgess (2012), mathematics and statistics share some pedagogical issues, however there are several statistical concepts that need to be particularly addressed in teacher development programs, whether in training prospective teachers, or during professional development for in-service teachers. The authors claim that statistics is supported by an investigative cycle (formulate questions, collect data, analyze data, interpret results) (Franklin et al., 2007), and it occurs enclosed within context.

Several researchers have suggested frameworks for making sense of teachers' understanding of statistics and their abilities to teach statistics. Burgess (2006) also proposed a

framework to explain statistical knowledge of teachers (SKT). In this framework, types of knowledge described by Hill, Ball, and Schilling (2008) as common content knowledge, specialized content knowledge, knowledge of content and students, and knowledge of content and teaching were considered along with the components of statistical thinking and empirical inquiry, which was proposed by Wild and Pfannkuch (1999). Similarly, Groth (2007; 2013) presented frameworks consisting of the components of statistical knowledge for teaching as common knowledge, specialized knowledge, mathematical knowledge, and nonmathematical knowledge. Further, Groth hypothesized that common and specialized knowledge were relative to the four phases of a statistical investigation as suggested in the GAISE K-12 framework (Franklin et al., 2007).

Reviewing most of the earlier frameworks presented above, Lovett (2016) proposed a conceptual framework showing how statistical teaching efficacy, statistical knowledge, and pedagogical statistical knowledge affect teachers' practices in teaching statistics. According to this framework, those three constructs (statistical teaching efficacy, statistical knowledge, and pedagogical statistical knowledge) are essential components for examining teachers' readiness to teach statistics. According to the author, those three constructs work together in explaining prospective mathematics teachers' readiness for teaching statistics, and are impacted by teachers' university or K-12 experiences, teaching experience, and world experiences with data and statistics.

Teachers' Beliefs and Attitudes in Statistics

Researchers have been investigating the role of beliefs in teaching and learning for a long time, however this history includes teaching in general or in mathematics, not in statistics specifically. Teachers' beliefs affect their actions in conducting statistics lessons. For example,

while teaching measures of central tendency, teachers' approaches could be affected by their beliefs about whether their students need practice to calculate the mean, or whether they should see the problems as associated with real situations, or whether technology might help them to learn, or whether it is important for students to learn how to choose the right measures of central tendency (Pierce & Chick, 2011) However, despite this likely impact, there has been little research about the role of teacher beliefs in teaching statistics.

Philipp (2007) defines beliefs as "psychologically held understandings, premises, or propositions about the world that are thought to be true" (p. 259). According to this definition, beliefs are considered as cognitive lenses through which one views the world. Pierce and Chick (2011) argue that beliefs could be held with "varying degrees of conviction, and may seem inconsistent or contradictory from an observer's point of view" (p. 260).

Philipp (2007) also defines attitudes by contrasting them from beliefs. He describes attitudes as manners of acting, feeling, or thinking that show a person's opinion or disposition. Different from beliefs, attitudes are often assessed with various scales, according to the author. According to Gal, Ginsburg, and Schau (1997) statistical beliefs affect the teaching/learning process, and the relationship with statistics beyond the classroom. Estrada, Batanero, and Lancaster (2011) point out that teachers' beliefs especially (and more importantly) affect students' relationship with statistics beyond the classroom. Remembering the main goal of statistics education as creating better statistical thinkers, teachers' beliefs, and thus their impact in students' relationship with statistics, would be destructive if they are negative (causing misconceptions, etc.).

Teachers' beliefs are related to teachers' experiences prior to teaching (Begg & Edwards, 1999), and therefore there should be differences between beliefs of teachers from different grade

levels (e.g. between primary and secondary level teachers), because those teachers might have experienced different statistics courses in terms of number, depth, and nature.

According to Pierce and Chick (2011), teacher beliefs related to teaching statistics could be analyzed in two ways:

1. Teachers' beliefs about statistics: discipline and curriculum issues

These types of teacher beliefs include (a) beliefs about statistics; (b) beliefs about the relationship between mathematics and statistics; (c) beliefs about the place of statistics in the curriculum. It is important to know whether teachers' beliefs about statistics are similar to statisticians' views about statistics, because their perceptions about statistics may suggest their desirable beliefs instead of appropriate concepts. To overcome this potential problem that could be caused by beliefs, Gattuso and Ottaviani (2011) suggest that teachers should see statistics as investigative processes in the context of societal activity, rather than procedural computations.

2. Teachers' beliefs about the teaching and learning of statistics

These types of teacher beliefs include (i) beliefs about why statistics is important for students; (ii) beliefs about teaching and learning statistics.

External factors, such as policies and curricular demands or assessment, may or may not enforce the ideas that students must learn statistics for living. These could cause teachers to develop varying beliefs about the nature and importance of statistics education.

Though not listed above, another factor affecting teachers' beliefs could be the beliefs caused by technology. Research about pedagogy of statistics teaching, misconceptions about statistical concepts, and technological developments rapidly grow. Teachers' instructional change (or transformation) has become a necessity. As in other subject areas, teachers' resistance to instructional change is mostly caused by their beliefs.

What do teachers' attitudes toward statistics tell researchers? According to Estrada, Batanero, and Lancaster (2011), teachers' positive attitudes towards statistics would help show that they "understand that statistics is useful in their students' professional and personal lives, and that their students can be trained to understand and use statistics" (p. 163, 164). According to authors, research about teachers' attitudes toward statistics is segmented into three themes: (i) measuring teachers' global attitudes towards statistics and comparing these attitudes with those of undergraduate students in other fields; (ii) focusing on a specific part of teachers' cognitive competence, namely, their attitudes towards their role in continuing to learn; (iii) analyzing teachers' attitudes in relation to teaching statistics. The authors state that research about identifying the factors influencing the attitudes of teachers' focuses on three themes: the relationship between attitudes and statistical knowledge, relating prospective teachers' attitudes to other affective variables, and assessing differences in attitudes in prospective and practicing teachers.

To understand prospective teachers' attitudes and misconceptions, Estrada, Batanero, Fortuny, and Diaz (2005) conducted an empirical study among preservice mathematics teachers. The authors found that there were five types of positive teacher attitudes while teaching statistics: considering statistics an easy topic; satisfactory learning experiences; novelty of the topic; perception of the usefulness of statistics for a teacher; the formative value of statistics. On the other hand, according to the authors, the negative attitudes were: lack of previous knowledge or training; difficulty with statistical reasoning; content too formal; considering statistics is undervalued in society; and a lack of knowledge of applications.

Estrada, Batanero, and Lancaster (2011) found that "positive attitudes increase when students have good learning experiences and perceived value for their own professional work or

for their students' education" (p. 170). In contrast, "negative attitudes are linked to perceived difficulty, lack of knowledge and overly formal content" (p. 170).

Lovett and Lee (2017) stated that preservice teachers were not well prepared to teach statistics. According to the authors, developing common statistical knowledge was not enough for being prepared to teach statistics. Preservice mathematics teachers should develop pedagogical statistical knowledge, and they also need to attend to noncognitive aspects of teaching, such as beliefs and confidence, which could impact their instructional approaches. The authors stated that teachers' beliefs were observed in two categories with respect to teaching statistics: teacher's beliefs in their ability to do statistics (statistics self-efficacy), and teachers' beliefs in their ability to teach statistics to bring about student learning (statistics teaching efficacy). The authors cited Molenberghs et al. (2014), who asserted that teachers were unwilling to teach statistics at the beginning, and they gained confidence as they taught it later. Lovett and Lee (2017) found that, besides other factors, teachers' statistics teaching efficacy was impacted by teachers' experiences and knowledge gained in their statistics and mathematics education courses about statistics.

More research (especially empirical research) is needed to examine teachers' beliefs and attitudes about statistics, the evolution of those beliefs and attitudes, and how those beliefs and attitudes affect teachers' teaching practices.

Teachers' Practices

In terms of classroom practices and designing course sequences, Forster and Wild (2010) addressed a criterion for statistics teaching. While designing a statistics course, the authors suggested that teachers focus on what students could be capable of doing at the end of the course. They present the following sequential criteria for teaching practices of statistics courses:

- Increase each student's technical capability (traditionally 'the content');

- Increase each student's integrative capability (ability for interlinking everything students have learned so far);

- Increase each student's recognitive capability (to recognize where their tools are likely to prove useful);

- Increase each student's distillery capability (to distill information and extract meaning);

- Increase each student's communicative capability.

According to Forster and Wild (2010), by using the criterion above, the course should benefit from existing capabilities of students (from prior courses) and develop upon those capabilities. The authors stated, "Almost all pedagogical attention in statistics has been focused on 'content', the first and easiest item (and even then, often degenerating to 'teach more topics'). By stressing writing, we can work simultaneously on the capabilities for integrating, distilling information and communicating" (p. 89).

Pfannkuch, Regan, Wild, and Horton (2010) suggest teachers should be able to tell the story in data. According to the authors, this storytelling requires natural language skills for explaining the reasoning of the content instead of using a heavily symbolic language, because students are not living in a world where they use symbolic language. If statistics is trying to help students understand real world situations with data as a tool, their language should represent that real world. According to the authors, "teachers can enhance and promote the true purpose of statistics: to learn more about real-world situations. This involves drawing inferences from sample data about a wider universe taking sampling variability into account and making a decision under uncertainty" (p. 16). The authors stated that understanding the connections

between specific contexts in the problem and underlying mathematical procedures is a critical requirement for statistics education.

The Role of Technology in Teaching Statistics

Technology use is now an essential aspect of the research about statistics education. This aspect brings more burdens to teachers. Chance, Ben-Zvi, Garfield, and Medina (2007) stated that technology triggered numerous changes in statistical practices in teaching, learning, and applying statistics. According to the authors, technology provides approximate solutions to strong and resistant issues about statistics. These allow the complex statistical models to become more simplified and usable, and thus those changes in statistical practice directly influence the way statistics is taught.

Using technology would help students learn fundamental statistical concepts more easily. Technology allows teachers to provide different ways of representing a data set; it also allows students to manipulate a representation while exploring a data set (Garfield & Ben-Zvi, 2007). Furthermore, technology could help students overcome an important issue in the learning of statistics: understanding abstract ideas under uncertainty. For example, by including instructional software in a statistics lesson, students could develop an understanding of the central limit theorem by building various populations and examining the distributions that are derived from those populations (Ben-Zvi, 2000).

Teachers need not only deep knowledge about statistics, but also deep knowledge about technological tools to use in exploring statistical ideas, and a depth of knowledge of pedagogical issues related to teaching and learning statistics with technology (Lee & Hollebrands, 2011). As addressed by Pfannkuch and Ben-Zvi (2011), there are enormous technological and ideological developments in the research field of statistics teaching, and those intensive and dynamic

developments could be another reason for resistance to instructional change among mathematics teachers. For example, the dynamic statistical software TinkerPlots (Konold & Miller, 2005) has become an integral part of the teaching, learning, and reasoning processes of statistics and thus, may affect teaching practices directly.

According to Pfannkuch and Ben-Zvi (2011), technological developments and developments in the approaches to statistical reasoning triggers a paradigm shift in the conceptualization of statistics teaching. Pfannkuch and Ben-Zvi (2011) indicate that mathematics teachers need to capture statistical knowledge and professional knowledge to teach statistics, and they also need a positive learning environment that can help foster a deep and meaningful understanding of statistics and the ability to think and reason statistically.

According to Lee and Hollebrands (2011), teachers need to have a thorough understanding and knowledge of technology use for teaching statistics. Technology integration into actual classes depends on three main factors: (i) statistical knowledge (content knowledge of statistics); (ii) technological statistical knowledge (understanding how to use technology to explore statistical ideas); and (iii) technological pedagogical statistical knowledge (understanding pedagogical issues related to teaching statistics).The authors indicate that "these factors impact teachers' decisions, and will ultimately affect whether the use of technology will enhance or hinder students' learning of statistics" (p. 359). The framework presented by Lee and Hollebrands (2011) included three layers of knowledge in order to explain teachers' technological pedagogical statistical knowledge (TPSK). Every component of this framework points to required knowledge domains for teaching (statistical knowledge (SK), technological statistical knowledge (TSK), and TPSK), thus, "some pedagogical component is blended in each aspect of the framework, albeit not always an explicit focus" (p. 361). According to that

framework, teachers' statistical knowledge is the largest needed set of knowledge to teach statistics; by time, teachers become more advanced in our technology-rich world.

The integration of technology in teaching and learning of statistics brought about the possibility to drastically change classroom practices and curriculum materials that have the potential to enhance students' learning of statistical concepts and methods (Ben-Zvi, 2000; Garfield & Ben-Zvi, 2008; Stohl, 2005; Lee & Hollebrands, 2011). The research about integrating technology into statistics education has increased enormously and continues at a rapid pace.

Improving practicing teachers' teaching of statistics requires ongoing professional development. The next section reviews literature related to teachers' professional development and teachers' education.

Models for Teachers' Professional Development

Professional development (PD) is an essential mechanism to deepen teachers' content knowledge and develop teachers' instructional practices (Desimone, 2009). Professional development is a common way to encourage teacher improvement in terms of knowledge, skills, beliefs, and, most importantly, teaching practices. PD usually comprises school-based, district-based, or conference-based workshops where teachers, principals, and researchers may participate (Ball, 1996; Hawley & Valli, 2000).

In a study intended to identify the characteristics of high quality professional development, Garet, Birman, Porter, Desimone, and Herman (1999) listed six professional development features that directly or indirectly relate to teacher improvement: activity type, activity duration, collective participation, focus on content, promotion of active learning, fostering coherence.

According to Sztajn, Wilson, Edgington, and Myers (2014), mathematics professional development (MPD) is a main space for educators and researchers in the field of mathematics education to exchange knowledge with their colleagues. According to the authors, MPD influences the practices of both teachers and researchers without reducing the importance of two kinds of practices. However, Sztajn (2011) discussed the need for standards to describe MPD in research reports about mathematics education. In order to meet the expectations of professional development efforts, high-quality reporting is necessary in the field. This touches the field of statistics education, as well.

Reporting standards are needed for professional development research about teachers of statistics. For planning and conducting meaningful and effective professional development in statistics education for teachers, it is vital to construct a picture of teachers' strengths and needs in the teaching of statistics. This picture should contain adequate information about teachers' statistical knowledge, beliefs about statistics, confidence about statistics, their education background, and their experiences (Wessels & Nieuwodt, 2011).

In the next sections, several professional development models will be described and compared.

Professional learning communities

The professional learning community (PLC) model represents an organizational approach which emphasizes participants' commitment to a mission of enhancing student learning, high levels of collaboration, and reflection on student and school data (DuFour, 2004). Garet et al. (1999) attempted to describe the features of professional learning experiences that connect to improvements in teachers' knowledge and skills, and to improvements in teacher instructional practices. In the PLC model, school leaders ask teachers to set up commitment (both individual and

organizational) to a shared goal about students' learning, and to work together with other colleagues to make decisions, collect, analyze, and interpret the data. The authors identified "six high-quality professional development features:

- activity type (for example, traditional workshops versus reform models, such as study groups or peer mentoring);

- activity duration (including both contact hours and span of time covered);

- collective participation (i.e., whether participants are grouped by some common characteristic, such as grade level, discipline, school);

- focus on content (i.e., the degree to which professional development develops teacher knowledge of content areas);

- promoting active learning (the extent to which teachers are "active" during professional development, such as observing other classrooms, planning class implementations, or reviewing student work);

- fostering coherence (the extent to which professional development connects to individual, school, or district goals and needs)" (p. 4).

Hord (1997) stated that PLCs are the communities where educators share and observe learning and reflect what they learned and observed in their practices. The main goal of those communities is to enrich their teaching effectiveness on their students' learning. The author pointed out that a limitation of these communities is the lack of working with actual students in a class, and she reminded the readers about the Japanese lesson study model, where teachers collaborate in a professional development setting by including direct work with students in several steps of the model.

Japanese lesson study

Japanese lesson study (JLS) is a teacher professional development model that is rooted in Japan and started to gain popularity in educational research in other countries, including the U.S., after the 1990s (Stigler & Hiebert, 1999; Lieberman, 2009). Particularly in the U.S., JLS is a model which provides opportunities to improve the overall educational system. JLS, or lesson study as it is known shortly, is a comprehensive process conducted by teachers in order to examine teaching practices that involve many teachers. This model could provide some solutions to the issues about teachers' professional development (Fernandez, Cannon & Chokshi, 2003). According to Lewis, Perry, and Hurd (2009), there are four main features of a lesson study: investigation, planning, research lesson, and reflection. The authors also address three pathways that improve teaching practice through a lesson study: changes in teachers' beliefs and knowledge, changes in professional community, and changes in teaching and learning resources.

Lieberman (2009) stated that there have been three characteristics of U.S. teachers that prevent them from dynamic and necessary instructional changes, including the use of the JLS model for teacher professional development: the norms of individualism, conservatism, and presentism.

- Individualism: American teachers do not have enough opportunities to observe other teachers, and to discuss their teaching practices with other teachers.
- Conservatism: Teachers are used to teaching the way they were taught to teach, and they reject taking risks by changing their teaching methods.
- Presentism: Teachers practice meeting only short-term goals for gaining immediate results or rewards.

According to Hiebert, Gallimore, and Stigler (2002), those teacher norms still exist, are difficult to overcome, and they mostly explain why American teachers are resistant to instructional change. It is tough for them to develop a professional body of knowledge which could be gained from a lesson study.

DuFour's model of PLC presents some efforts to overcome the problematic U.S. teacher norms (individualism, conservatism, and presentism), however, these efforts are not very strong, because according to research, the issues are still present when it comes to observing changes in teachers' instructional practices. Those problematic norms still need to be addressed. The PLC model seems to be a good effort where PD experiences are carried from out-of-school gatherings or workshops into the schools, however, it still lacks a vital characteristic which JLS has: involving teachers' simultaneous participation and direct work with students.

According to Lieberman (2009), teachers could change their instructional practices by professionally interacting with other teachers. During this interaction, teachers might develop new skills and knowledge or strengthen the skills and knowledge they already have, thus those interactions could impact their professional identities as teachers. Lieberman indicates that this interaction, could eventually overcome the problematic norms (individualism, conservatism, presentism) by replacing them with the norms of openness, collaboration, and experimentation. The author recommends professional development researchers use JLS methods for building PLCs.

Learner-centered professional development

Hawley and Valli (2000) presented the learner-centered professional development (LCPD) model, where the goal is connecting student learning directly to teacher learning. This model recognizes the schools as complex organizations, learning as an interactive process, and

teachers as competent learners. For testing this model, one could investigate whether teachers'

learning activities changed teachers' instructional practices and whether these changes in

practice contributed to students' learning.

Polly and Hannafin (2010) synthesize empirical studies and recommendations for

proposing a framework to guide the efforts of LCPD. According to Polly and Hannafin, learner-

centered teaching had the potential to improve teachers' practices especially in known

problematic areas. The authors address the National Partnership for Excellence and

Accountability in Teaching's (NPEAT, 2000) recommendations for LCPD-based

implementations and the American Psychological Association's (APA) principles for effective

professional development, and then present six principles to conduct a well-established LCPD.

Those principles are: PD needs to focus mainly on student learning; PD must be teacher-owned;

PD needs to develop knowledge of content and pedagogies; PD needs to be collaborative; PD

needs to be ongoing; PD needs to be reflective.

As with other models, LCPD also has some limitations. For example, as of today, the

connections between professional development, teachers' learning, class implementation, and

students' learning are still not very strong. More empirical studies are needed to strengthen those

connections.

Online professional development

According to Hawley and Valli (1999), many researchers consider professional

development as the keystone for educational improvement. However, face-to-face professional

development sometimes cannot fit into teachers' schedules, and resources are often not locally

available, thus they become difficult to conduct. Therefore, an evolutionary path toward real-

time, ongoing, work-embedded professional development has led to the creation of many online

teacher PD programs (Dede et al., 2009). With online PD programs, more teachers are able to

attend a professional collaboration and find their voice and learn from others in more flexible

discussion times. "The availability of attractive online options not available in pure face-to-face

teacher professional development is one reason why many programs are moving to blended or

hybrid models that attempt to combine the strengths of both" (p. 10).

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). An online community

includes: (i) people who interact socially while trying to satisfy their needs and perform roles;

(ii) a common purpose which provides motivation for the community; (iii) some policies for

guiding the participants' interactions; and (iv) computer systems for supporting and mediating

the interactions and to facilitate a sense of the togetherness (Preece, 2000).

Lock (2006) stated that online communities have the potential to facilitate teacher

professional development if the educators change their perceptions of professional development.

In order to do that, the educators need to build new perspectives for professional development by

considering teachers' needs and expectations within online communities and recognizing the

possible diversity within the communities. Online professional development programs may have

a variety of participants from all around the world with similar interests and goals. To foster a

learning culture, dynamic learning environments should be carefully and deliberately designed.

This requires "a pedagogical framework that nurtures the establishment of relationships,

intimacy, and trust, where people engage in shared learning experiences mediated through

technology" (p. 668). The participants should not be only observers or consumers of the

knowledge but should also be contributors. In order to conceptualize online PD, a culture shift is

also required. The transition from traditional PD to online PD changes teachers' beliefs and

practices, and also transforms their approach to PD. Online communities also function out of

traditional practices, and this provides "a new appreciation of how and when they can engage in

community and provides new possibilities for how the community can evolve over time to

support their just-in-time needs and to foster ongoing opportunities for teacher renewal" (p. 675).

Researchers have found that online professional development (OPD) that addresses the

varied needs and abilities of its participants can be effective in changing teachers' instructional

practices (Lee, Lovett & Mojica, 2017). According to the authors, in order to achieve this,

designers of PD should include personalized, accessible, and meaningful works which could

affect teachers' beliefs, practice, and knowledge.

Massive open online course

The idea of massive open online course (MOOC) is that the course is scaled to reach as

many learners as possible. MOOCs were founded in 2007, via an open online course at Utah

State University and Regina University, taught by David Wiley and Alec Couros. However, the

popularity increased when the "Introduction to Artificial Intelligence" MOOC (called xMOOC)

was offered free to anyone by Sebastian Thrun and Peter Norvig at Stanford University in 2011.

160,000 people from all around the world were enrolled in this course (Hill, 2012).

Lieberman and Mace (2008) state that by forming and/or joining online teaching/learning

communities, teachers will expand their circle of like-minded colleagues, because those kinds of

communities would allow geographically dispersed members to meet, exchange ideas, and learn

from others. MOOCs could be used as a good example for online PLCs.

MOOCs provide unique opportunities. The data collected through the course could be

amazing, considering the diversity and number of participants included. The participants could

be diverse in several ways (language, origin, background, age, reason for enrollment, etc.)

(Breslow et al., 2013). MOOCS are reduced in cost to the participant and expanded in the amount of course participation. According to Mazoue (2013), accredited universities started to give partial credit toward a degree through MOOCs, and probably in the near future, there will be entirely free online programs in accredited institutions, with a degree obtainable through only MOOC credits. Besides, and maybe because of all these good qualities, MOOCs have some challenges, too. One issue is the verification of the quality of a given MOOC. MOOCs provide a much different platform in which creating course norms are difficult. "Although improving the quality of student learning is one of the priorities of the major MOOC providers, most of their courses currently lack a sophisticated learning architecture that effectively adapts to the individual needs of each learner" (Mazoue, 2013, p. 14).

When offered for teachers (to train teachers), MOOCs are a form of professional development. However, using conventional PD approaches is costly and not effective in this form of PD. According to Kleiman, Wolfe, and Frye (2013), new approaches 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 the massive open online course for educators (MOOC-Ed), which provides opportunities for using research-based practices, along with new technological tools and facilitation approaches for delivering quality PD.

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). This approach guides us to conceptualize psychological models of educational decision-making. 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. Participants' ongoing interactions in a MOOC may shape both their psychological states and their practices.

Avineri, Lee, Lovett, Gibson, and Tran (2016) found that MOOC participants take advantage of the purposeful design of the course, thus designing a MOOC with set goals and principles would influence the overall results of MOOC research. According to the authors, using frameworks and research-informed practices in teaching statistics are very important and valuable, and these help participants view the teaching and learning of statistics more comprehensively and more conceptually.

To elaborate on a theoretical perspective and framework to guide our study, the next section is a research review of teachers' professional growth and what influences that phenomenon.

Teachers' Change / Teachers' Professional Growth

Change sequences and professional growth

According to Clarke and Hollingsworth (1994; 2002), professional growth is represented as the inevitable and continuing process of learning. In my opinion, this claim is a very assertive one, though. If the subject were only 'change,' instead of 'professional growth,' there would be no reason to argue about it, because, I believe that anything changes with time and intervention (here, the intervention is learning). However, the change is not always in a positive direction, thus professional growth is not inevitable, but change is. Professional growth is ideal, though.

Putting this strong allegation to the side, Clarke and Hollingsworth (2002) provided details for an empirically grounded model of professional growth which includes key features of contemporary learning theory. This model explains existing research data on teachers'

professional development and recommends key considerations for in-service and preservice teacher training programs. The authors describe six perspectives about teacher change:

1. Change as training: Change is something done to the teachers (teachers are changed);

2. Change as adaptation: Teachers change in response to something; they adapt their practices to changed conditions;

3. Change as personal development: Teachers seek to change to improve their performance or develop additional skills or strategies;

4. Change as local reform: Teachers change something for reasons of personal growth (the one I will use for the study);

5. Change as systemic restructuring: Teachers enact the change policies of the system;

6. Change as growth or learning: Teachers change inevitably through professional activity; teachers are themselves learners who work in a learning community.

The authors state that those perspectives listed above are not mutually exclusive and they are interrelated. Most PDs align with the change as growth or learning perspective. In this perspective, change is identified with learning, and it is described as "a natural and expected component of the professional activity of teachers and schools" (p. 948). Historically, teacher change has been directly linked with planned professional development activities.

Clarke and Hollingsworth (2002) stated that teachers' effectiveness is measured by professional growth. Again, in my opinion, this is again a strong claim, but a less disputable one. Does professional growth directly influence teachers' practices? Is there any strong evidence for this? As far as the review made by the authors, the answer was unclear. In my opinion, theoretically there could be independence between these two variables (teacher's professional

growth and teacher's effectiveness). Effectiveness should be measured with exterior measurements (students' learning outcomes, students' satisfaction, assessment scores, etc.), where professional growth could be just an internal change, where teacher intellectually changed, but are not able to transfer this change effectively to his/her students.

Until the 1990s, teachers' change was linked to planned professional development activities (Clarke & Hollingsworth, 1994), and it was rooted on a paradigm which implied a deficit in the skills and knowledge of teachers (Guskey, 1986). Professional development mostly contained one-time workshops for helping teachers develop skills and knowledge in a context. Many researchers criticized this approach due to its ineffectiveness (Howey & Joyce, 1978; Wood & Thompson, 1980; Guskey, 1986; Clarke & Hollingsworth, 1994). The deficit-training-mastery model has been left behind, and there has been a focused shift from the idea of change as an event with teachers as passive participants to change as a more complex process which involves learning (Fullan & Stiegelbauer, 1991). The teacher-change programs then shifted to teachers as active learners shaping their growth (professional growth) through their reflective participation in PD programs and in their actual practices (Clarke & Hollingsworth, 2002). Another old mistake was the assumption that professional development would trigger change in teachers' beliefs and attitudes and thus they would be expected to change their practices (Fullan, 1982) Guskey criticized this model, because according to the author, significant changes in teachers' beliefs and attitudes might take place after obvious changes in learning outcomes of students. Instead, Guskey proposed his model of the process of teacher change, where professional development causes change in practice, practice causes change in student learning outcomes, and finally that causes change in teachers' beliefs and attitudes. Clark (1988) opposed this model by proposing a cyclic model with multiple entry points; according to this, teacher

change was not a strictly linear process, but was better explained as an ongoing cyclical process. A further model to explain the process of teacher change was developed by an international group of researchers (Teacher Professional Growth Consortium, 1994), as the interconnected model of teacher professional growth. The interconnected model of teacher professional growth suggests that professional growth (change) occurs through the mediating processes of reflection and enactment in four domains that encompass the teacher. These domains are (i) the personal domain (teachers' knowledge, beliefs, and attitudes); (ii) the domain of process (teachers' professional experimentation); (iii) the domain of consequence (salient outcomes of PD); (iv) the external domain (sources of information, stimulus, and support). These four domains are analogues to Guskey's linear model's domains. The model includes the mediating process of reflection and enactment mechanisms in which change in one domain triggers a change in another domain (Hollingsworth, 1999). This model (the change environment or the interconnected model of professional growth) will be used as the model for explaining teachers' change or professional growth in this study and will be described more in the next section.

Impact of PDs on Teachers' Practices

According to Dunne, Nave, and Lewis (2000), the practices of PD participants became more student-centered over time, because teachers "increased the use of techniques such as added flexibility of classroom arrangements and changes in the pace of instruction to accommodate for varying level of student content mastery" (Vescio, Ross & Adams, 2008, p. 83). Measuring the effectiveness of PD by building a comprehensive picture of all facets that contribute to effective teaching practices requires multiple approaches, such as written assessments, interviews, observations, discourse analysis, and teacher reflections (Shulman, 1987; Watson, 2001; Hill et al., 2007; Wessel & Nieuwoudt, 2011).

To measure the effectiveness and quality of PD, Ingvarson, Meiers, and Beavis (2005) developed an instrument (Quality of Professional Learning Index) and identified some characteristics of effective PD. Those characteristics are (i) content focus; (ii) follow-up; (iii) active learning; (iv) feedback; (v) collaborative examination of student work. The authors selected four measures of impact: impact on teachers' knowledge, impact on teachers' practice, impact on students' outcome, and impact on teacher efficacy. Since a part of the focus in this study is on the measure of impact on practice, this measure will be highlighted. For measuring the impact on practice, the authors asked teachers whether, as a result of their participation in the PD, they now, for example, make clearer links between their teaching goals and class activities, manage classroom structures and activities more effectively, use more effective teaching and learning strategies appropriate to the classroom context, and so on.

According to the authors, to conclude that PD was positively effective on teachers, a strong relationship between content focus and reported impact on practice should be noted. This is supported by research suggesting "a strong knowledge base and a clear theoretical rationale grounded in research were required for effective PD programs (Joyce & Showers, 1982; Kennedy, 1998; Hawley & Valli, 1999)" (p. 16).

On the other hand, Guskey (1985) states that the more effective strategy to assess the impact of PD on teachers' practices is for teachers to try out new practices based on their learning and observe the effects of these new practices on their students, instead of changing their teaching attitudes and hoping that that would lead to a direct change. Thus, modeling effective practices and inviting teachers to try them out in actual classrooms would be a positive characteristic of a professional development program.

A common argument is that to be effective in practice, teachers should have a fundamentally strong command of the material they teach (CBMS, 2012). Borko (2004) also argues that, for enacting students' conceptual understanding, teachers should have rich and flexible knowledge of the concepts they teach. Teachers' command of and confidence in teaching the subject influences what they teach and the way they teach it (NCTM, 1991). Thus, PD programs which focus on subject-specific content could help teachers enhance their understanding of the subject, and better equip them to teach the subject in more depth (Borko, 2004). With this enhanced understanding, teachers could better design and implement effective tasks and assessments, engage their students in richer conceptual discussions, and anticipate students' questions and misconceptions (Avineri, 2016).

Additionally, research shows that PD programs that focus on both subject-specific content knowledge and pedagogical content knowledge could have positive effects on teaching practices and learning outcomes. According to Corcoran (1995), such PD programs are critical in effecting teacher practice changes. Also, Garet et al. (2001) found that "PD programs with a focus on content as a 'core feature' had a substantial positive effect on participants' knowledge and skills" (p. 933).

Theoretical Perspectives and Framework

Overview

The primary goal of the TSDI MOOC is to assist participants in achieving several objectives listed below. Similarly, in the PLTs, participants and groups are assisting each other in achieving these goals, as well as making progress toward other goals that a PLT may set for themselves (e.g., improve use of technology in our introductory statistics courses). We are

looking for change based on the foci of the course. TSDI MOOC is designed considering the following course objectives:

- Strengthen understanding of how to engage students in a statistical investigation process;

- Explore a framework for guiding teaching of statistical investigations to promote deeper data explorations for students;

- Use rich data sources and dynamic graphing tools to support investigations of questions that are of interest to teacher and students;

- Examine the ways students reason with data to make evidence-based claims;

- Personalize applications of statistical investigations to students;

- Collaborate with colleagues near and far to gain different perspectives on data investigations and to build a library of teaching resources.

When teachers participate in the TSDI MOOC and are part of a smaller PLT, teachers' change is expected to occur in teachers' individual learning path as a MOOC participant, as a teacher of statistics, and through their participation as a PLT member.

Both a MOOC and a PLT represent a community of practice (CoP). 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, 2001). A CoP has three main characteristics: the domain, the community, and the practice. In this study context, the TSDI MOOC and PLT have a shared domain, and that is teaching statistics. TSDI MOOC is a much larger CoP with much more variability in the contexts of participants' educational practices; TSDI MOOC's practices are more varied than PLT. On the other hand, PLTs include more practices that are shared by the members of PLT; for example, PLT members actively and purposefully meet and discuss closely

what they have recently learned in TSDI MOOC.

Most PDs align with Clarke and Hollingsworth's (1994) "change as growth or learning" perspective on teacher learning. In this perspective, change is identified with learning, and it is regarded as a natural and expected component of the professional activity of teachers and schools (Avineri, 2016). Historically, teacher change has been directly linked with planned professional development activities (Clarke & Hollingsworth, 1994). The interconnected model for professional growth will be the foundation for a framework to guide this study. The model has three domains of practitioners' individual professional world (personal domain, domain of practice, and domain of consequence), and one shared domain (external domain). In order to investigate the research questions, the enactments and reflections between these domains will be analyzed and discussed.

The next section will attempt to describe the learning theory which best corresponds to the aim of this study (active-situated learning). Then the community of practice will be explained as an explanatory concept for PLTs. Finally, the interconnected model for professional growth will be elaborated in detail as the overall framework used to answer the research questions.

Active-situated learning

According to situated learning theorists, learning is enhanced when it is done purposefully and actively. Accordingly, teachers should have opportunities to engage in active learning (e.g., solve problems, address questions, complete activities in the role of students) that promote their professional growth and help them to make sense of what they learn in meaningful ways (Darling-Hammond et al., 2009). Active learning provides learners (or teachers as learners) motivation for changing through personally meaningful experiences, and active engagement respects adults as professionals and provides them voice and choice in shaping their own

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learning (Killion & Crow, 2011). Through their active engagement, teachers could construct an individual meaning of what they learned, and they are likely more committed to success, and identify applications for what they have learned. Thus, active learning processes promote deeper understanding of learning and increase teachers' motivation for implementation (Avineri, 2016).

Teachers should engage actively throughout their PD experiences. Lave and Wenger (1991) claimed that if PD were delivered in a situated environment in which teachers collaboratively engage in learning activities, they would grow professionally. The authors argued that "activities, tasks, functions, and understandings do not exist in isolation; they are part of broader systems of relations in which they have meaning" (p. 53). Clarke (1994) included this point as one of the key characteristics of effective PD and argued that those settings provide teachers the potential to develop a "clear vision of the proposed changes" promoted by the PD program (p. 38).

Researchers suggested that PD programs aligned with situated learning could have positive influences on teachers' practice (Herrington & Oliver, 2000; Garet et al., 2001). In a study where this idea is also addressed and supported, Ingvarson et al. (2005) stated that PD programs including the main measures of active (situated) learning theory (the extent to which the PD program provides opportunities for teachers' reflection on practice; the level at which teachers actively engage in identifying their needs and goals for the PD program; and, the extent to which the PD program offers opportunities to implement new practices) would be positively effective in changing teachers' practice and thus increase students' achievement. Avineri (2016), discussed Ingvarson et al.'s three measures to provide additional insight into their definition of active learning and its role in supporting effective PD. According to her, reflecting on practice provides participants an image of their work as they planned and implemented that practice,

which gives them an opportunity to also be critical about this work. For example, these opportunities could be used for refining practices by considering alternative approaches to teaching certain subjects, posing better questions, and analyzing interactions with students in the classroom.

Teachers in the U.S. are not provided enough opportunities to actively plan, reflect, and receive feedback on their practice (Clarke, 1994). Therefore, physical conditions may prevent teachers from being able to grow in their own practices. Thus, they are being left to the opportunities given by PD programs. This gives PDs a much more vital role. Exchanging ideas, experiences, and challenges among teachers provides them opportunities to learn different teaching approaches, validate or invalidate their practices, and construct a communal understanding to share similar challenges. Through reflection, teachers could develop an awareness of tacit assumptions, beliefs, and views, and they could also develop coherent rationales for their views, assumptions, and actions, and become aware of viable alternatives (Thompson, 1992). Teachers who are engaged with and supported by colleagues with common experiences are more likely to apply what they learn in their teaching practices (Simoneau, 2007). According to the author, "learning is the process of constructing personal understanding through interactions with others while collectively engaging in challenges that are novel and transferable to other situations and settings, is transformational" (p.1).

Research also suggests that PD programs that engage participants in identifying their own goals have a positive impact on teachers' practice (Clarke, 1994; Hawley & Valli, 1999; Avineri, 2016). Self-directed learning (SDL) is a key term for expanding teachers' participation to be open to professional growth during PD. Knowles (1975) defines self-directed learning (SDL) as "a process in which individuals take the initiative, with or without the help of others, to diagnose

their learning needs, formulate learning goals, identify resources for learning, select and implement learning strategies, and evaluate learning outcomes" (p. 18). deWaard et al. (2015) examine the existence of SDL in their MOOC study participants. According to the authors, SDL is personal and critical to success, because it allows participants to determine whether they achieved what they intended from their engagement in the learning environment and how they did it. Thus, SDL provides opportunities for increasing the potential for self-directed PD to be effective. Daley (2001) stated that sustained, ongoing learning is also important for PDs. "Professionals make meaning by moving back and forth between continued professional education and their professional practice" (p. 39). This could include teachers' self-analysis of their teaching by watching video-recordings of their teaching sessions. As they view recordings with their colleagues during planning periods or within professional learning community (PLC) meetings, teachers could discuss their strengths and weaknesses and develop strategies for improvement through these discussions (Clements et al., 2011). These provide opportunities for teachers to reflect on their own context which is critical for professional growth. (Borko et al., 2005**;** Webster-Wright, 2009).

Communities of practice

According to Allee (1997), a community of practice (CoP) is a group of individuals who are informally bound to other individuals in the group through exposure to a similar set of problems and activities for the common pursuit of solutions. Wenger (2001) defines CoP as "a group of people who share an interest in a domain of human endeavor and engage in a process of collective learning that creates bonds between them: a tribe, a garage-band, a group of engineers working on similar problems" (p. 2). A CoP has three main characteristics: the domain, the community, and the practice.

We should explicitly emphasize the components of a community of practice, as they will be a part of the external domain of the main framework in this study. Thus, the following will elaborate on how the professional learning teams will correspond to the components of CoP.

- The domain: Involvement in the community requires some knowledge and some competence in the focus area or domain (Wenger, 2001). In the context of this study, the domain is teaching statistics through data investigations (TSDI).

- The community: Members of the community interact and learn together, "they engage in joint activities and discussions, help each other, and share information" (Wenger, 2001, p. 2). In the context of our study, there are two community levels possible; one is a TSDI MOOC community, and the other is a PLT community. Joint activities and discussions are forum discussions for the first level, and the PLT meetings for the second.

- The practice: Members of the community "develop a shared repertoire of resources: experiences, stories, tools, ways of addressing recurring problems--in short a shared practice" (Wenger, 2001, p. 3). In the context of our study, the practice is improving teaching of statistics.

In this study, the three components of CoP listed above will be included as components of external domain in the interconnected model for change.

Online communities of practice

Avineri (2016) stated that the benefits of online communities of practice (CoP) are not always afforded in traditional face-to-face PD. For example, online CoPs provide participants "extended access to resources and expertise beyond the immediate school environment" (Mackey & Evans, 2011, p. 11), thus online CoPs provide an ongoing PD and a possible increase in classroom learning applications. Herrington, Reeves, and Oliver (2009) argued that educators

achieved implementing new pedagogical strategies in their practices when they receive the support of their online CoP. To make online CoPs more beneficial, online PD programs should be able to construct the necessary ground for supporting these communities, because the members of PD do not physically engage in activities together. Discussion forums within the online PD must be very carefully constructed so that the prompts offer opportunities to reflect on teaching practices, to exchange opinions and cognitive (or practice) issues, and discuss different teaching strategies (Treacy, Kleiman & Peterson, 2002). If interactions and discussions within the online PD are designed well, these online CoPs would provide the members opportunities "to engage learning that will be sustained and relevant, as knowledge is enhanced through the exchange of thoughts and insights among CoP, and skills are developed with a focus on specific needs" (Simoneau, 2007, p. 7).

The interconnected model of professional growth

The interconnected model of professional growth is briefly explained above. The external domain is located outside the teacher's personal world. The other three domains (the personal domain, the domain of practice, and the domain of consequence) include teacher's professional actions, the inferred outcomes of these actions, and the belief and knowledge that prompted these actions (Clarke & Hollingsworth, 2002). Teacher's change or professional growth may occur in any of these three domains as external domain processed. As an example, "experimentation with a new teaching strategy would reside in the domain of practice, new knowledge or a new belief would reside in the personal domain, and a changed perception of salient outcomes related to classroom practice would reside in the domain of consequence" (p. 951). Through the mediating process of reflection and enactment, a change in one domain would effect a change in another domain.

According to the model, change can be in any of the four domains, and the change type would reflect the particular domain. For instance, implementing a new teaching method would belong to the domain of practice, a new belief or knowledge would belong to the personal domain, and a perceptual change in classroom practice would belong to the domain of consequence. The model includes the mediating process of reflection and enactment mechanisms in which change in one domain triggers a change in another domain (Hollingsworth, 1999). This model (called the change environment or the interconnected model of professional growth) is used as the model for explaining teachers' change or professional growth in this study, and updated to frame this study, as seen in Figure 1.

As seen in the figure, the domains of the interconnected model are described within the context of this study and will subsequently be further described.
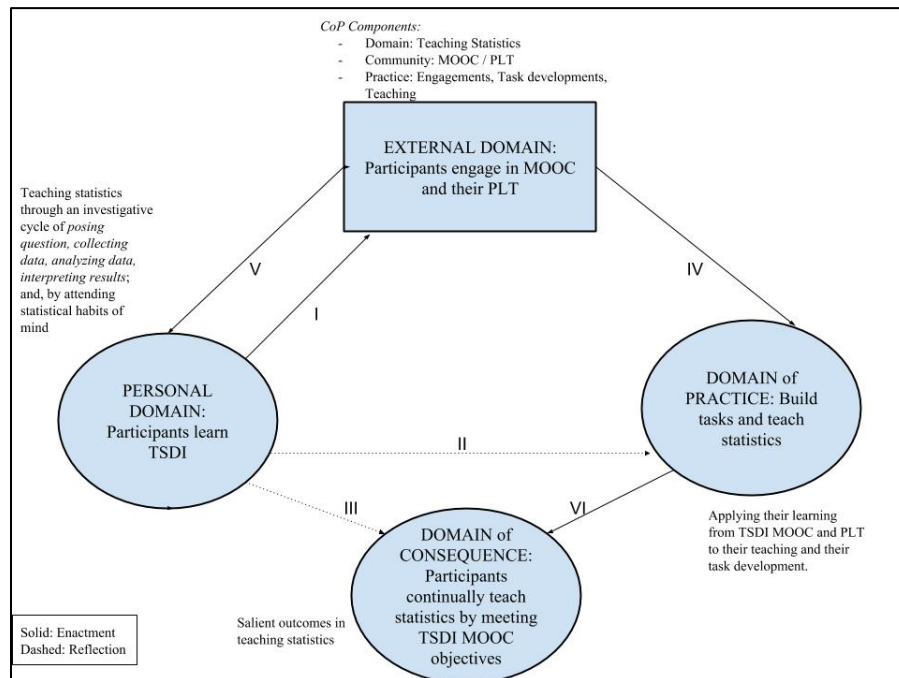
Figure 1. The interconnected growth model for blended PDs of MOOC and PLT

External domain includes participants' engagement in the activities and interaction with others within the MOOC and their PLT. As a community of practice, both communities reflect the three characteristics of a CoP, where the community and practice components will mainly differ from a larger community (MOOC) to a smaller one (PLT).

Personal domain includes the participants' learning of the TSDI course objectives (strengthen understanding of how to engage students in a statistical investigation process; explore a framework for guiding teaching of statistical investigations to promote deeper data explorations for students; use rich data sources and dynamic graphing tools to support investigations of questions that are of interest to teacher and students; examine the ways students reason with data to make evidence-based claims; personalize obligations of statistical investigations to students; collaborate with colleagues near and far to gain different perspectives on data investigations and to build a library of teaching resources), their understanding of SASI framework and statistical habits of mind, their individual engagement with the course, and their ability to build pedagogical knowledge and confidence about teaching statistics.

Domain of practice includes participants' applying their learning from MOOC and PLT experiences to their practice of statistics teaching (actual teaching practices, building statistical tasks, etc.), their approaches to important issues about statistics teaching, and their challenges in statistics teaching practice.

Domain of consequence includes participants perspectives about teaching statistics practices, teachers' salient adaptation of new methods in their teaching practices (as guided by TSDI course objectives [change from instruction-as-usual to teaching statistics through data investigation], by attending SASI framework, and considering the statistical habits of mind while teaching).

The main question when applying this framework to the study will be: Does teachers' participation in the external domain impact changes in the personal domain, domain of practice, and domain of consequence? The study is blending two professional developments: a massive open online course (MOOC) and professional learning team (PLT). Participants engage with the course content and other participants in the MOOC (through forums); they also engage with others in PLT meetings. Do these engagements impact teachers' (i) learning of TSDI course objectives; (ii) teaching practices; (iii) perspectives of teaching statistics? If yes, how does that change occur? Several hypotheses will be listed as examples of possible changes.

Descriptions of constructs (interconnections between different domains [arrows])

According to Clarke and Hollingsworth (2002), there are two different mechanisms (or two mediating processes) to account for change or professional growth effects: enactment and reflection. Enactment is the mechanism by which a teacher puts a new idea, belief, or a practice into action. For example, in this study, a teacher's increasing use of statistical investigative cycles in the tasks used in their classroom represents the enaction of a newly developed understanding of the nature of a statistical investigation. Reflection, on the other hand, is defined as "active, persistent, and careful consideration" (directly quoted in [Clarke and Hollingsworth, 2002, p. 954], from [Dewey, 1910, p. 6]). For example, a teacher's reflections on how to use the newly learned teaching methods from PLT meetings represent a reflection mechanism. Change or professional growth could occur within each domain separately, or through the enactment and reflection processes. To answer the research questions of this study, the following constructs are provided as guiding hypotheses.

I.   Personal domain >> External domain: I hypothesize that the participants' learning of TSDI MOOC objectives through their participation in MOOC influences the MOOC

community and PLT. For example, a teacher may share this learning through MOOC discussion forums and build a new discussion thread where other participants also find opportunities to engage and change. Similarly, PLT meetings include members' sharing of these learning experiences, thus a teacher's learning of new pedagogical knowledge or building confidence would directly affect the climate of the PLT. (*Enactment*)

II. <u>Personal domain >> Domain of practice:</u> I hypothesize that the participants' learning of TSDI MOOC objectives influences their teaching practices (including class teaching and their task development). For example, a teacher's learning of new pedagogical knowledge through a MOOC would enhance the quality of a statistics task that the teacher develops for students. *(Enactment)*

III. <u>Personal domain >> Domain of consequence:</u> I hypothesize that the effects of participants' learning of TSDI MOOC objectives in their engagement in MOOC and PLT, and in their task development and concurrent teaching practices, influences teachers' perspectives about teaching statistics (i.e., these effects deepen participant's understanding of what it means to teach statistics). *(Reflection)*

IV. <u>External domain >> Domain of practice:</u> I hypothesize that participant engagement in MOOC and PLT influences their teaching statistics practices. For example, as teachers engage with others in PLT meetings, they may learn about a strategy they did not know of before, and they may transfer this new strategy to their class teaching practices. *(Enactment)*

V. <u>External domain >> Personal domain:</u> I hypothesize that participants' engagements in MOOC and PLT influences their knowledge of and confidence in teaching statistics. For example, a teacher explores a conceptual misconception discussed in a MOOC forum and

realizes that he/she also has that misconception and tries to overcome it. (*Reflection)*

VI.   Domain of practice >> Domain of consequence: I hypothesize that changes in

participants' teaching statistics practices will impact their perspectives about teaching

statistics and deepen their understanding of teaching statistics. For example, by applying

the investigative cycle in task development and observing positive outcomes in students'

learning, teacher may integrate the use of the investigative cycle to statistics course

planning, and this may become a salient method the teacher uses. *(Enactment)* (It is

important to note that I do not expect to see much evidence about this hypothesis in this

study because observing the change in domain of consequences would require further

observation of teachers' teaching practices).

It is important to note that change does not occur only through interconnections; each

domain of the interconnected model of professional growth is a change domain too (Clarke and

Hollingsworth, 2002). The characteristic of change, however, differs as change in external

stimuli, change in practice, change in salient outcomes, and change in knowledge or beliefs. The

following is an explanation of how the changes could occur in domains.

(i) The external domain: In the embedded case study outlined above, MOOC and PLT

both provided new information and new stimulus for the participants. The teaching method

presented in MOOC, the way a participant engages with others in MOOC and PLT, and the value

attached to sharing ideas and perspectives with others both in MOOC and in PLT represent

external changes.

(ii) The domain of practice: The use of a new method in teaching statistics (teaching

statistics through data investigation) as the teachers actually teach statistics and as they develop

tasks for students' use will be examined to see whether or not changes occur in practice. For

example, a participant's post-task differs from his/her pre-task by attending the phases of statistical investigative cycle and statistical habits of mind.

(iii) Teacher knowledge, beliefs, and attitudes (the personal domain): Change in teacher beliefs and attitudes could be observed in the value that the teacher attaches to a method that represents new pedagogical knowledge for that teacher.

(iv) The domain of consequence: Change in this domain is tied to participant's inferences that are drawn from his/her practices. For example, an increase in a teacher's use of the investigative cycle in teaching statistics or attending the statistical habits of mind in developing tasks, would count as a positive change.

This framework and hypotheses of potential changes are used to inform the data collection and analysis in this study, as explained in the next chapter.

CHAPTER 3: METHODOLOGY

Study Design

The study uses phenomenological case study design using a group of 63 PLT and MOOC participants and two in-depth cases (Stake, 2005) of a PLT leader and a PLT member. Both qualitative and quantitative data are collected and analyzed simultaneously. Phenomenology is interested in the study of experiences from the perspective of participants and emphasizes the importance of individual perspectives and interpretation (Lester, 1999). Also, phenomenological research is "powerful for understanding subjective experience, gaining insights into people's motivations and actions" (p. 1). According to Creswell (2007) phenomenological research attempts to describe the meaning of lived experiences for several individuals and focuses on "describing what all those individuals have in common as they experience a phenomenon" (p. 57). In this kind of a research, first, it is essential to identify the phenomenon, and then the researcher collects data from experiencing individuals and composites a "description of the essence of the experience for all of the individuals" (p. 58). That description should include both what those individuals experience, and how they experience it. Creswell advocates that researchers should include some discussion about the philosophical background of phenomenology, because the approach is rooted in philosophy. For example, Creswell emphasizes that Moustakas (1994) has devoted more than one hundred pages to explain philosophical assumptions about phenomenology before he starts presenting the methods of his study.

The philosophical background of phenomenology is based on a mathematician and philosopher, Edmund Husserl (1970) who described this approach as an objection to scientism, which focused on exploring the world only by attending the empirical means. Before Husserl, by

the end of 19th century, the field of philosophy was heavily focused on "scientism," which basically suggested understanding and exploring the world by only empirical means. Husserl, and several famous colleagues and followers (Jean Paul Sartre, Martin Heidegger, Marleau Ponty) suggested to return to the perspective of traditional Greek philosophers, and value the search for wisdom to explore the world, instead of only attending to the empirical means. Husserl suspended the pre-developed judgments about what is real on a certain basis and called this suspicion "epoche." According to this, the reality was not a summation of subjects and objects, but it was a Cartesian diagram of subject and object as they appear in our consciousness (Creswell, 2007). "The reality of an object is only perceived within the meaning of the experience of individuals" (p. 59). Another reason to choose phenomenology is that it supports the idea that learning is situated; Husserl (1970) states that individual perspectives of lived experience would evolve over time as individuals interact with their peers and with social contexts (Purcell-Gates, 2004). As social contexts and environments constantly change within a given *lifeworld* (the concept *lifeworld* is used in philosophy and in sociology), the world "as lived" prior to reflective representation or theoretical analysis (Husserl, 1970), then the interpretation by individuals upon his/her experience would be unique.

In this study, the purpose is to understand and describe the phenomena of participating in a massive open online course and a professional learning team to improve the teaching of statistics. There is a case group of 63 individuals who participated in this blended professional development opportunity during 2016-2017.

Context of the Online Course

The Teaching Statistics Through Data Investigations (TSDI) course is a massive open online course for educators (MOOC-Ed) designed to strengthen participants' skills and prepare

them to use a statistical investigation cycle to teach statistics and help students explore data to make evidence based claims (see http://go.ncsu.edu/tsdi). There is a two-step registration process; first registration is for the platform that offers the course along with other MOOCs, and the second registration is specifically for the course.

There are five units in the TSDI MOOC course. Unit 1 is titled Considering the Possibilities of Teaching Statistics with Data and focuses on what statistics is and why it is taught in schools. Unit 2 is titled Engaging in Statistics, and it offers a careful look at what it means to engage in statistics. Unit 3 focuses on Introducing Levels of Statistical Sophistication and presents a framework for supporting growth in students' statistical sophistication and digs deeper into statistical habits of mind. Unit 4 is titled Delving Deeper into the Investigation Cycle, and it provides teaching and learning materials to assist participants in understanding the different components of a statistical investigation, including several resources that can be used directly with students. Finally, Unit 5 engages participants in Putting It All Together to consider how to change teaching practices that can really engage students in doing statistics with real data. Each unit is similarly structured by containing the following sections: hear from your instructor; engage with essentials; learn from our expert panel; dive into data; investigate: assessment items; discuss with your colleagues; extend your learning; demonstrate your learning; and unit feedback survey. The course includes instructor videos explaining the units, expert panel videos, videos of real students and teachers engaging in statistics work, animations depicting student work in statistics, brief readings, excerpted readings from articles or books, various data analysis tools (open source), and lesson plans, tasks, online apps, and videos that can be used in the classroom. For example, Figure 2 shows the "Engage with Essentials" page in Unit 1 with the sections of the unit labeled on the left for easy navigation.

Figure 2. Engage with Essentials page in the TSDI MOOC.

Each unit includes two discussion forums, one connected with the main investigation in the unit, and the other where participants can drive the conversation about aspects of their practice or discuss other elements they are learning about in the unit or specific resources shared in the unit.

The course offers a 20-hour certification for teachers upon completion, and micro-credentials to participants who complete the specific requirements. Most importantly, the course provides a unique opportunity to everyone interested in learning about better ways to teach statistics.

The Framework

Recall from Chapter 2, a framework was presented to provide a lens for understanding

teachers' growth when engaged in professional development (Clarke & Hollingsworth, 1999).

Figure 3 (Figure 1 is repeated here) provides details for how it will frame the data collection and

analysis.
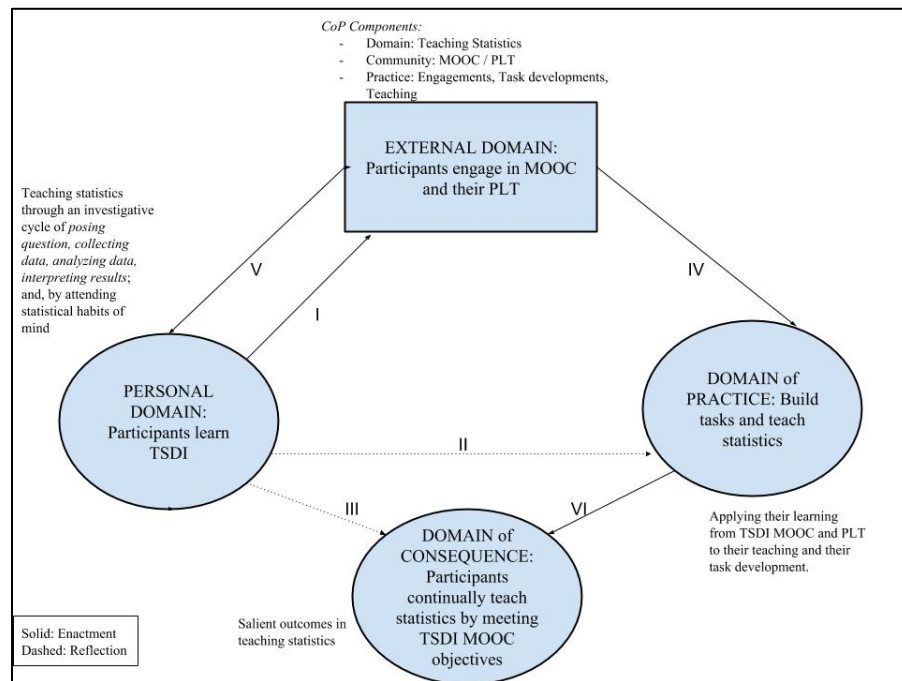
Figure 3: The interconnected model of professional growth in teaching statistics through blended
professional development

Teachers' change or professional growth could occur within each domain separately, or

through the enactment and reflection processes. In order to examine professional growth, the

following constructs are provided as guiding hypotheses. However, in order to answer the

research questions of this study, the focus will be on three domains (personal domain, domain of

practice, and external domain) and only explore in depth two hypotheses concerning the impacts

one domain may have on another (Construct IV: External domain >> Domain of practice;

Construct V: External domain >> Personal domain). While not a focus of this dissertation,

hypotheses III and VI may play a role in how the researcher needs to make sense of the

phenomena under study. All six are explained below.

I. <u>Personal domain >> External domain:</u> I hypothesize that the participants' learning of TSDI MOOC objectives through their participation in MOOC influences the MOOC community and PLT. For example, a teacher may share this learning through MOOC discussion forums and build a new discussion thread where other participants also find opportunities to engage and change. Similarly, PLT meetings include members' sharing these learning experiences, thus a teacher's learning of new pedagogical knowledge, or building confidence would directly affect the climate of the PLT.

II. <u>External domain >> Domain of practice:</u> I hypothesize that the participants' learning of TSDI MOOC objectives influences their teaching practices (including class teaching and their task development). For example, a teacher's learning of a new pedagogical knowledge through a MOOC would enhance the quality of a statistics task that teacher develops for student.

III. <u>External domain >> Domain of practice:</u> I hypothesize that participants' engagements in MOOC and PLT influence their teaching statistics practices. For example, as they engage with others in PLT meetings, they may learn about a strategy they individually did not know of before, and they may transfer this new strategy to their class teaching practices.

IV. <u>Personal domain >> Domain of consequence</u>*:* I hypothesize that the effects of participants' learning of TSDI MOOC objectives in their engagement in MOOC and PLT, and in their task development and concurrent teaching practices influences teachers' perspectives about teaching statistics (i.e., these effects deepen participant's understanding of what it means to teach statistics).

V. <u>External domain >> Personal domain:</u> I hypothesize that participants' engagement in the MOOC and the PLT influences their knowledge of and confidence in teaching statistics. For example, a teacher explores a conceptual misconception discussed in a MOOC forum and realizes that he/she also has that misconception and tries to overcome it.

VI. <u>Domain of practice >> Domain of consequence:</u> I hypothesize that changes in participants' teaching statistics practices will impact their perspectives about teaching statistics and deepen their understanding of teaching statistics. For example, by applying the investigative cycle in task development and observing positive outcomes in students' learning, a teacher may integrate the use of the investigative cycle to their whole statistics course planning, and this may become a salient method the teacher uses.

Participants and Consent

The largest group in this study is all TSDI MOOC participants (804 enrolled participants in total) for fall 2016 and spring 2017. The case of interest for this research are the 63 TSDI MOOC participants that also joined one of nine professional learning teams (PLT). There were four PLTs formed during fall 2016, and five PLTs formed during spring 2017. As shown in Figure 4, the study focuses on understanding the experiences of members of the nine PLTs situated within the larger MOOC community to find out about their lived experiences in participating in both the TSDI MOOC and PLT, and how it may or may not impact their classroom practices and perspectives about teaching statistics.
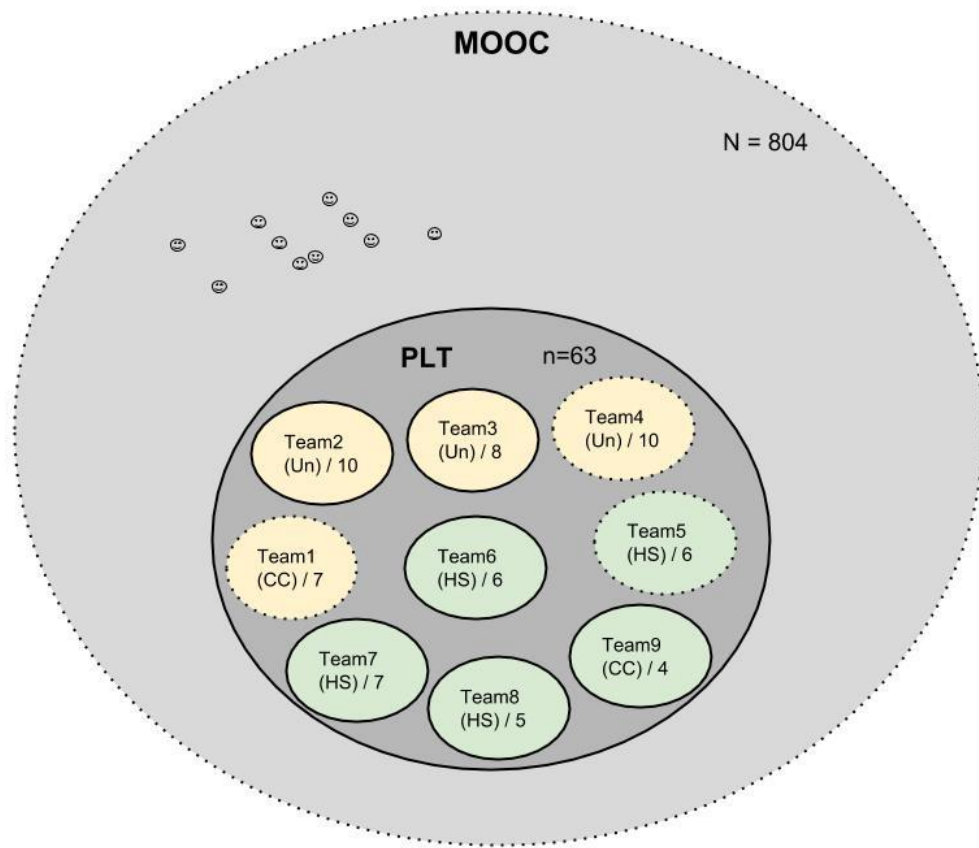
Figure 4: Blended professional developments: MOOC and PLTs

As seen in Figure 4 above, there is a large community that both PLT members and non-PLT members are a part of; it is the set of all MOOC participants (MOOC) consisting of 804 participants. There is a subset, the case focus for this study, which represents the PLT teams (PLT), consisting of 63 participants. PLT sets consists of nine subsets, which represent each PLT (Team 1, Team 2, etc.). Those nine teams have different characteristics depending on the grade level members teach; team leaders' background (whether the leader is a former TSDI MOOC participant or not); and the way they conduct their PLT meetings (virtually or face-to-face). The dashed outline means that the community met virtually and a solid outline means that the community met face-to-face. Yellow sets of PLTs were the groups led by former TSDI MOOC

participants; green ones are PLTs led by first time TSDI MOOC participants.

For fall 2016, 316 former active TSDI MOOC 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 (see Appendix A) indicating they wished to lead a team. The research team considered their interest form 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. 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 or hold any PLT meetings. Thus, that team was eliminated, and four teams were successful in completing the PLT project. Fall PLTs had three teams consisting of university instructors and students, and one that included community college teachers. Two teams held meetings virtually, and two held meetings face-to-face.

As a different strategy, in spring 2017, instead of contacting former TSDI MOOC participants again, 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 team. Four of those teams, in Hawaii, Nebraska, Michigan, and New York, scheduled face-to-face meetings. One team was formed with members from different locations in the U.S. and scheduled virtual meetings. Spring teams included four teams of high school teachers and one team of community college instructors.

All participants in the MOOC agree upon registration that the data generated during their participation in online activities in the MOOC can be used for research purposes. All PLT members are asked to sign an informed consent form for participating in this research and for any data to be collected outside of the MOOC environment (Appendix B). Nine PLT participants, including all four team leaders, consented to participate during fall 2016, and seven participants consented during spring 2017. Table 1 provides information about each professional learning team that participated in this research.

Table 1. *PLT team information*

Team	Grade / # of participants / Location	General Description
Team 1	Community College / 7 / NC	The team was led by a former MOOC participant. The team consisted of 7 community college teachers from two institutions in NC. 6 members completed the process. 6 meetings were held virtually.
Team 2	University / 10 / NY	The team was led by a former MOOC participant. The team consisted of 10 university instructors from the same university in New York. Meetings were held face-to-face.
Team 3	University / 8 / MI	The team was led by a former MOOC participant. The team consisted of 6 university instructors and one graduate student from the same institution in MI. All members completed the process. 6 meetings were held face-to-face.
Team 4	University / 10 / NV	The team was led by a former MOOC participant. The team consisted of 8 graduate students in an elementary math education department in NV. 6 members completed the process. 6 meetings were held virtually.
Team 5	High School / 6 / (several east coast states)	The team was led by a first time MOOC participant. The team consisted of 6 high school mathematics teachers. All members completed the process. The teachers were a part of a separate project about statistics education and teach in different locations on the east coast. Five meetings were held virtually.
Team 6	High School / 6 / HI	The team was led by a first time MOOC 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 / 7 / MI	Former MOOC participant 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 /5 / NE	The team was led by a first time MOOC participant. The team consisted of 4 high school teachers teaching at the same public school in Nevada. 2 members completed the process. The 10 meetings were held face-to-face.
Team 9	Community College / 4 / NY	The team was led by a first time MOOC 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.

Data Sources

Several types of data were collected for this study. According to Creswell (2013), it is important to collect multiple forms of data and, themes should be used for performing a qualitative analysis properly across that data. The sources of data for this research came from the Teaching Statistics through Data Investigation massive open online course (TSDI MOOC) offered during fall 2016, TSDI MOOC offered during Spring 2017, and the PLT project conducted in both semesters simultaneously with TSDI MOOCs. The following table (Table 2) provides a summary of the data sources aligned with the framework and research questions. Details about the data sources and analysis follow.

Table 2. *Research questions-data sources-framework-analysis*

Research Questions	Connection to the Framework	Data Sources	Analysis Approach
1a) In what ways does participating in a MOOC and in a PLT focused on teaching statistics impact teachers' professional growth in perspectives and beliefs about teaching statistics?	Construct V: External domain >> Personal domain (*Hypothesis:* Participants' engagements in a MOOC and a PLT influences their knowledge, beliefs, perspectives, and confidence in teaching statistics.)	Forum discussions, PLT meeting notes, end of course and follow up surveys, interviews *Interview question #5:* "Throughout the meetings, how have your perspectives about teaching statistics changed or not?"	A priori (Avineri et al. elements in form of lived experiences) and open coding (PLT-related, or other lived experiences in the phenomenon)
1b) In what ways does participation in a MOOC and a PLT focused on teaching statistics impact teachers' professional growth in confidence to teach statistics?	Construct V: External domain >> Personal domain	- Quantitative data from SETS confidence survey offered during Unit 1 and Unit 5, measuring the gain score; - Open response in SETS; - Unit 5 discussion forum; - Follow up surveys and interviews	Compute gain scores, using t-test for quantitative analysis Coding qualitative data for mention of increased/decreased confidence and experiences that may have impacted confidence.

Table 2. *continued*

Research Questions	Connection to the Framework	Data Sources	Analysis Approach
1c) In what ways does participating in a MOOC and a PLT focused on teaching statistics impact teachers' professional growth in understanding how to support students' approaches to statistical investigations?	Construct V: External domain >> Personal domain	- Discussion forum threads of PLT members; - PLT meeting summaries; - PLT interviews *Interview question #5:* "Please tell me about your small group meeting (PLT), and how you interacted in those? Throughout the meetings, how have your perspectives about teaching statistics changed or not?"	A priori (MOOC elements in form of lived experiences) and open coding (PLT-related and/or other lived experiences in the phenomenon)
2) How does participation in a MOOC and PLT impact the planned or self-reported use of various instructional strategies for supporting students approaches to statistical investigations?	Construct IV: External domain >> Domain of practice	- MOOC unit feedback and EOC surveys; - MOOC forum discussions; - PLT follow up surveys; - PLT meeting summaries; - Interviews (reflective) *Interview question #9:* "Do you think your teaching of statistics has been impacted? Describe how your learning and engagements in the TSDI MOOC and PLT community impacted your statistics teaching practices?" *Interview question #10:* "If we walked into a class where you were teaching a statistics lesson, describe what we would see." (reflective)	A priori (MOOC elements in form of lived experiences) and open coding (PLT-related and/or other lived experiences)

The data sources for this research include two types of sources: activity from within the MOOC and from outside the MOOC. Data collected within the online course environment or collected because the participant is a MOOC member include: Self-Efficacy for Teaching Statistics (SETS) survey, unit feedback and end of course surveys, follow up impact survey, participants' online course activities (viewed through the *Tableau dashboard* of the course), participants' forum posts, and meeting summaries. Data collected because participants are a member of a PLT include: PLT meeting summaries (meeting notes and PLT leaders' post meeting snapshots), PLT leaders' and PLT members' follow up surveys, and PLT leader and PLT member interviews. More information about these data sources is given below.

To situate the phenomena of 63 PLT members as also members of a larger MOOC community, data logs from the MOOC are examined to provide a description of the ways PLT members engage in the MOOC and if there are any notable differences between regular MOOC participants and PLT-MOOC participants. These data logs have been transformed into visuals and descriptive statistics within a Tableau dashboard (consisting of MOOC activity trends, click log, course completion) created by the Friday Institute MOOC-Ed team. This interactive tool is used to get a visualization of participants' MOOC activity. By selecting several target activities relevant to our investigation, and adding filters for PLT participants, the MOOC activity is examined based on trends, click logs, and course completion. The dashboard is an overarching tool that is used to situate the case study and describe the MOOC and PLT-only participants' patterns of engagements holistically.

Data Sources and Measures to Answer Research Question 1

The first research question is:

1. In what ways does participating in a MOOC and in a PLT focused on teaching statistics impact teachers' professional growth in:

   a. Perspectives and beliefs about teaching statistics?

   b. Confidence in teaching statistics?

   c. Understanding how to support students' approaches to statistical investigations?

To answer this question, several measures and data sources that will be explained in the following paragraphs.

Forum discussions are from the TSDI MOOC platform. There are 10 discussion forums in total. In a discussion forum, participants start different threads of conversation. Only the threads in which PLT participants engaged are used as data sources.

The Self-Efficacy for Teaching Statistics Survey (SETS; Harrell-Williams et al., 2014; Harrell-Williams et al., 2017) is designed to evaluate participants' confidence about teaching various aspects of statistics (e.g., estimate a population mean or proportion using data from survey; calculate the correlation coefficient between two variables, using technology; interpret measures of association). According to Lovett (2016), the SETS survey aligns with Bandura's (2006) construct of self-efficacy measuring expectations, and it measures teachers' efficacy for tasks and task levels that align with the GAISE framework. Those levels (Levels A, B, and C) are considered to have increasing statistical sophistication. The levels are aligned to some specific statistical content. Level A represents topics for novice statistics learners; Level B represents more complex content; and Level C represents more advanced content (Franklin et al., 2007). The SETS instrument consists of 44 items which are categorized as Level A, Level B, and Level C items. 11 items in the SETS instrument correspond to GAISE Level A; 15 items correspond to GAISE Level B; and 18 items correspond to GAISE Level C. The SETS

instrument has been validated as an appropriate instrument to measure confidence, on a scale from 1-6, for each of the 44 items, for teaching statistics in both middle school and high school preservice mathematics teachers. For each item in the SETS survey, participants rate their confidence in teaching 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. Content validity is established using experts' (college-level statistics educators, including teacher educators) judgement, focus groups (preservice and in-service teachers), and several pilot studies. Structural, substantive, and content validity evidence for the scores from the SETS instrument were outlined, and confirmatory factor analysis results provided evidence for treating the SETS as a two-dimensional (for SETS-Middle School, Harrell-Williams, Sorto, Pierce, Lesser, & Murphy, 2014), and three-dimensional (for SETS-High School, Harrell-Williams, Lovett, Lee, Pierce, Lesser, & Sorto, 2017) instrument aligned with GAISE Pre-K-12 framework. Within the TSDI MOOC, the SETS surveys are given to the participants twice. Participants can take the survey while they are in Unit 1 of the course (pre-SETS), and the survey is again available in Unit 5 (post-SETS). 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 (See Appendix C for SETS instrument).

Unit feedback, end-of-course, and follow up surveys are the surveys the TSDI MOOC participants are asked to complete after each unit they finish in the course, and at the end of the whole course. 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. They are opportunities for participants to self-assess their experience and evaluate the course. Out of 63 PLT participants, 39 participants (18 during fall 2016, and 21 during spring 2017) took a unit feedback survey, and 27 participants (10 during fall 2016, and 17 during spring 2017) took the end-of-course (EOC) survey. An example of a Likert-scale question and an example of an open-ended question are given below.

- EOC survey, question #1 (Likert-scale): *"*As a whole, how effective was this MOOC-Ed in supporting your personal and/or professional learning goals?" (1-very ineffective to 5-very effective)

- EOC survey, question #2 (open-ended): "What was the most valuable aspect of this MOOC-Ed in supporting your personal or professional learning goals?"

After they completed the MOOC and their PLT meetings, participants were sent a PLT follow-up impact survey. In total, 22 participants (7 PLT leaders and 15 PLT members) completed the follow-up surveys.

PLT meeting summaries (meeting notes and post-meeting snapshots) include my meeting notes about participants' interactions with others, about their reflection on their learning and experiences in TSDI MOOC and their teaching practices, and also, the PLT leaders' post-meeting snapshots. PLT leaders were asked to fill out a short survey after each PLT meeting, called post-meeting snapshots. Leaders' responses provided details about how their perspectives have changed through the time. Each leader did not complete the post-meeting snapshot for each meeting held. Thus, the meeting summaries only represent a portion of all PLT meetings held. Those two data sources (observation and leader's post meeting snapshots) are reported as

meeting summaries to provide information about the meetings. (See Appendix D for post-meeting snapshot survey)

Data Sources and Measures to Answer Research Question 2

The second research question asks how participation in a MOOC and a PLT impact the planned or self-reported use of various instructional strategies for supporting students approaches to statistical investigations.

To answer this question several measures and data sources explained in the following paragraphs are used.

PLT tasks ask PLT members to submit a statistics task they develop prior to their PLT experience, and another one (or the same, if they prefer) after the course and meetings end. The purpose of this data source is to measure teachers' growth in understanding of the SASI framework and other TSDI MOOC course objectives. Unfortunately, there is incomplete data for this source, because most of the PLT members did not upload their tasks. Thus, this planned data source was eliminated from the study.

As described above, PLT meeting summaries are a compilation of researcher's meeting notes for those meetings attended, and post meeting snapshots completed by leaders.

Self-reported notes include forum posts and open-ended questions in surveys (unit, end-of-course). The data are used to understand participants' reflections on what they learn and how they use this learning in their teaching practices. Two data sources were used to answer both questions. These data were collected several weeks, and sometimes months, after the PLT members and leaders had completed their experiences with the TSDI MOOC and the PLTs. Thus, these data sources are reflective in nature as participants recall their experiences and report on the impact these may have had on their perspectives and teaching practices.

PLT participants were asked to complete a PLT follow-up survey about their reflection on their MOOC and PLT-related learning and experiences. The surveys consisted of both Likert-scale and open-ended questions. (See Appendix E)

To gain information directly from the perspective of the PLT members, interviews were conducted with seven PLT leaders and six PLT members. The interview protocol (see Appendix F) includes direct and indirect interview prompts to gain information about the phenomena of participating in both a MOOC and a PLT. Interview questions are designed to specifically investigate the constructs derived from the interconnected model of professional growth (six framework constructs described earlier). There are questions about all the constructs because interviews are reflective data sources where it is possible to gain the most comprehensive responses about the blended professional development project. The interviews are conducted when participants are finished with the participation processes, and their learning and experiences are accumulated. Due to the distributed nature of the PLT groups, the interviews are conducted through an online tool such as ZOOM, Google Hangout, or Skype. It is important to note that because the interviews were semi-structured, new questions sometimes emerged based upon interviewee's responses. Table 3 shows how some interview questions are related to the research questions, and Table 4 lists the data source types and quantities.

Table 3. *Interview prompts' connection to the research questions*

Interview question	Framework connection	Research question
Q4: Please describe the things you have learned throughout your experiences as a TSDI MOOC and PLT participant.	*Construct V:* External domain >> Personal domain	*Research question 1a:* In what ways does participating in a MOOC and in a PLT focused on teaching statistics impact teachers' professional growth in perspectives and beliefs about teaching statistics?
Q9: Describe how you think that your learning and engagements in the TSDI MOOC and PLT community impacted your statistics teaching practices?	*Construct IV:* Personal domain >> Domain of practice	*Research question 2:* How does participation in a MOOC and PLT impact the planned or self-reported use of various instructional strategies for supporting students' approaches to statistical investigations?

Table 4. *The list and descriptions of the data sources*

Data Source	Type	Description	n
SETS survey	Mixed	Self-Efficacy for Teaching Statistics (SETS) survey results. Quantitative data from 44 Likert scale questions, and qualitative data from one open-ended question.	28
TSDI MOOC surveys	Mixed	TSDI MOOC surveys (unit feedback [32], end of course [28]). The surveys contained both Likert scale and open-ended questions.	60
PLT surveys	Mixed	PLT surveys (follow-up surveys [23], post-meeting snapshots [18])	41
Data logs	Quantitative	Complete course data logs for all registered MOOC participants	804
Forum discussions	Qualitative	TSDI MOOC forum discussion threads that included at least one PLT participant entry.	212
Meeting observations	Qualitative	Researcher's notes from PLT meeting observations.	22
PLT interviews	Qualitative	PLT leader and PLT member interviews	13

Data Analysis

As described earlier, the purpose of this study is to understand and describe the phenomena of participating in a massive open online course and professional learning team. The artifacts that are analyzed to obtain this goal are the TSDI MOOC activity of participants (SETS surveys, end of unit surveys, end of course surveys, tableau dashboard items [MOOC activity trends, click log, course completion], MOOC forum posts, PLT leader post-meeting snapshots, PLT follow-up surveys, PLT members' interviews, and the PLT meeting summaries. The following describes the analysis plan used for this study.

The first phase of analysis focused on discussion forums and open-ended responses on end-of unit and end-of-course surveys in the MOOC. Both MOOC survey responses and forum data initially included all MOOC participants' responses and discussion entries. First, these data were cleaned to make sure that unrelated data was excluded. I used acronyms for PLT participants, changed the real names to acronyms throughout the data, and filtered the discussion threads. For forum discussions, I selected only the discussion threads that contained at least one PLT participant entry (n=212) and excluded the threads only containing non-PLT participants' entries. Then, the discussion threads that included at least one PLT participant entry were transformed into PDFs, and all the PDFs were uploaded into Atlas.ti. Then each entry of a PLT participant was considered a unit of analysis and coded. Atlas.ti qualitative analysis software allowed for coding directly from time-stamps within a media file. The responses were analyzed with both a priori and open coding. The essential lived experiences were determined after filtering the results. The most prevalent lived experiences related to professional growth of teachers were documented and then re-examined as other qualitative data was collected.

For MOOC survey data (SETS open-ended, unit feedback, end-of-course) I selected only

the responses of PLT participants and excluded the others. Then the surveys were converted to PDF documents and uploaded into Atlas.ti. Each response was considered a unit of analysis and coded. For PLT survey data (follow-up surveys and PLT leader post-meeting snapshots), participants' responses to open-ended questions were filtered, converted to PDFs, and uploaded into Atlas.ti.

Audio and/or video files of PLT interviews were transcribed, converted to PDF, and uploaded into Atlas.ti. Each interview response was considered a unit of analysis and coded. Even though the interview questions include all the constructs in the theoretical framework, the main two constructs (External domain >> Personal domain and External domain >> Domain of practice) were the focus for analysis, since these were the constructs directly related to the research questions. However, information gained from the other questions was used to situate the phenomena and describe the interactions among all the domains in the framework.

PLT meeting summaries included both PLT leaders' post meeting surveys and my own PLT meeting notes from the meetings I joined. Post meeting surveys included both open-ended and Likert scale questions. Likert-scale questions include the following questions along several others: "Meeting helped me learn new things related to teaching statistics;" "PLT members seemed comfortable in this meeting;" "PLT members seemed to deepen their understanding of the content we discussed;" "PLT members were enthusiastic in participating in this meeting." The PLT leaders were asked to rate the extent to which they agreed on these statements. Some examples of open-ended question are as follows: "Did you discuss issues/content that was NOT part of the TSDI MOOC in your meeting?" and "What recommendations, if any, do you have for improving the experience in PLT meetings?" These surveys were not completed after every PLT meetings. The ones in hand are used to help understand the phenomena of being a PLT and

MOOC participant. PLT meeting summaries also included my meeting notes, where interactions and dialogue (from consenting participants) were included. Those data were not coded as other qualitative data. Instead, I used those summaries essentially to frame and provide more elaborate details for the narrative vignettes in Chapter 5.

The goal of this phase of coding was to identify the major lived experiences within the phenomenon of participating in a MOOC and a PLT. The qualitative data analysis of PLT-related data began with coding for these MOOC-related lived experiences, but also PLT-related lived experiences were identified using open coding (eclectic coding). A coding manual is built to discuss the functions of codes, coding, and analytic memos (Saldana, 2015).

The process of finding those lived experiences took weeks of reading and coding qualitative data, reading related research papers, and most importantly, discussing with my dissertation chair. I started with four lived experiences derived from previous research on the TSDI MOOC. Lee, Lovett, and Mojica (2017) conducted a study using fall 2015 TSDI MOOC participants to examine the impacts on teachers' beliefs and perspectives about statistics. They open-coded discussion forum posts and open-ended responses to surveys to find shifts in perspectives and course elements that appeared to trigger those changes in perspectives. According to that study, there were four elements in the TSDI course that triggered changes in perspectives: (i) SASI framework; (ii) the expert panel video discussions and the videos of students and teachers engaged in statistics tasks; (iii) the use of technology for visualizing data; (iv) the use of real data sources that are multivariable and messy. The qualitative data from MOOC forums and open-ended responses on surveys (follow-up, unit feedback, end-of-course surveys, and post-meeting snapshots) were initially coded using those four MOOC elements within lived experiences guided by a focus on change in teaching statistics. For example, instead

of a code of "SASI framework," I used "learning about and applying SASI framework" as a code; instead of technology, I used "learning about and engaging with technology;" instead of real and messy data, I used "learning about and engaging with real and messy data." For the element about the videos in the MOOC, first I used "observing and learning from the videos;" but after long discussion with my dissertation chair, we decided to divide this lived experience with videos into two, thus I ended up using "observing practices from videos," and "listening and reflecting upon expert panel discussions." I also open coded for additional lived experiences in the phenomenon that emerged and developed additional potential impacts. Those additional lived experiences mostly came from the PLT, and there were many at the beginning. Four lived experiences were identified as essential and creating impacts with other lived experiences; those were sharing about personal practices, unpacking MOOC materials, encouraging each other to progress, and being concerned about content or practice. Again, the process of open-coding and identifying additional lived experiences included several discussions with my dissertation chair. Those discussions changed the number and the description of the lived experiences used as codes. There were 29 lived experiences at the beginning of coding. At the end, these were collapsed and reorganized into nine salient lived experiences. All nine lived experiences will be explained in detail with examples. These lived experiences were finalized as essential after a long and intense initial coding. As I coded the data, I named new lived experiences. The codes were checked through independent review of a sample of data by the dissertation chair, and any disagreements were negotiated, revised, and then reapplied to the body of data.

The following figure (Figure 5) represents an example of coding a discussion forum thread. There are two TSDI MOOC participants, one a PLT member (*PLT38*), and one non-PLT participant. Only the post from the PLT member is coded. In that example, open coding was

conducted, and the codes that were applied were not the finalized codes. After discussions with the dissertation chair, the essential lived experiences were reapplied to the data.
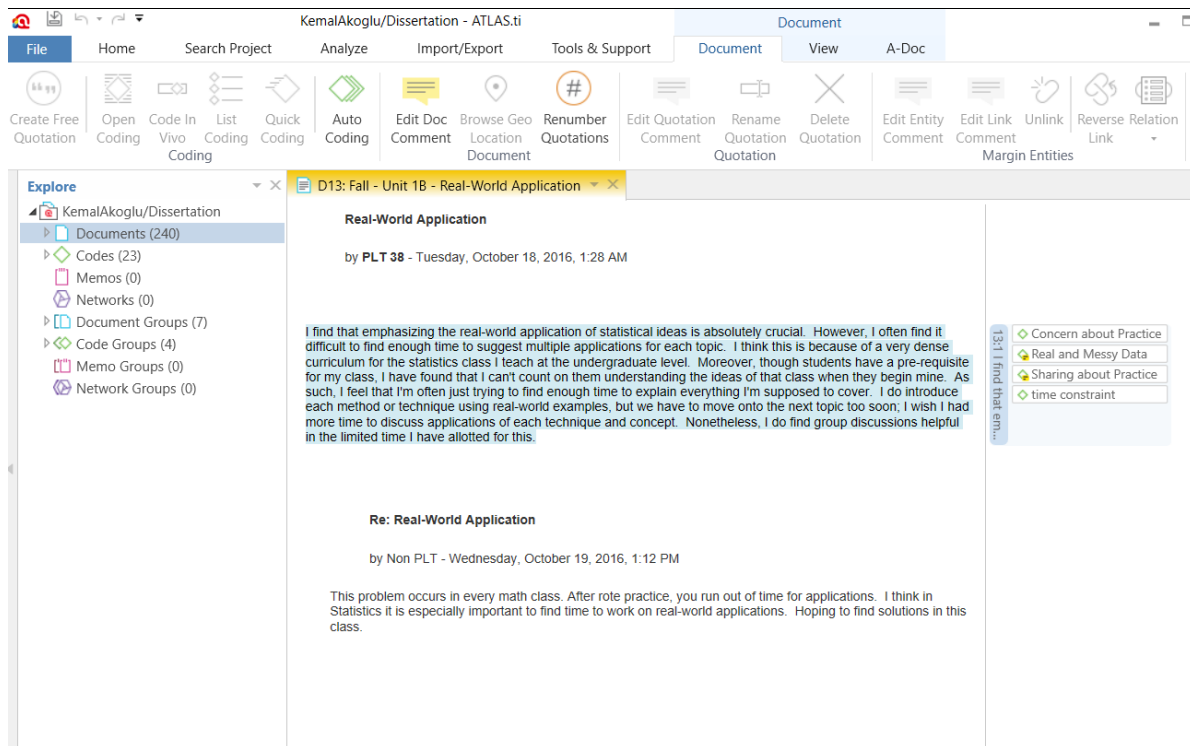
Figure 5: An example of coded forum discussion

After getting the final lived experiences, the impacts in teachers' perspectives about and practices in teaching statistics were identified. Those impacts were related to one or more lived experiences. The impacts were discussed with the dissertation chair in detail. These are presented in more detail in Chapter 4.

The quantitative data for this research included SETS survey results and Likert-scale responses to unit, end-of-course, and follow-up surveys, and data logs from MOOC activity. The statistical method for analyzing the SETS survey results is to examine scores for their total confidence pre and post, as well as gain scores for each level (A, B, C) of statistical

sophistication of topics. Dependent samples t-test was used to determine if there were significant differences in their gain scores using STATA 14 statistical analysis software. It is important to note that not all pre-test takers took the post-test. Thus, the PLT participants who took the post-test are identified and pre-test takers are filtered to be in the same group. The SETS questionnaire has 44 Likert-scale prompts; these prompts are separated into three blocks, and each block represents different levels of sophistication (A, B, or C). The analysis is conducted for every sub-scaled score of these different levels and for the total. Other quantitative data (Likert-scale responses to survey questions) is analyzed by using the numbers or percentages when needed, and as stated before, they were used as a secondary data source for confirming or refuting claims generated through qualitative coding.

Tableau dashboard items (MOOC activity trends, click log, course completion) were used throughout data analysis. Registration and click log data is displayed in a dashboard in Tableau software that allowed us to visualize participants' engagement over time and with certain types of resources. The dashboard was able to filter by role of PLT member or non-PLT member, so that it was possible to examine and report on trends of PLT participants' MOOC activity. Descriptive statistics and graphical displays are used to examine engagement patterns.

Ethical Considerations

The Internal Review Boards (IRB) of North Carolina State University (Submitted to NCSU eIRB system on 11/08/2016 and approved with the protocol number 9365) has approved this research.

All interviews were conducted after the participant completed the TSDI MOOC and PLT meetings. This is done so as not to effect participants' professional learning and experience.

It is anticipated that there is minimal risk for this study. Pseudonyms will be used in place

of participant names in all publications of this work. Participant work, participant identification, and all other artifacts for this project are and will be stored on a password-protected computer. The backup files are stored on an encrypted hard drive, which is stored in a locked office.

Some potential for researcher bias needs to be discussed. Most of my educational experiences related to teaching statistics have been situated in a university context. The PLTs with participants from universities were more familiar to me as the researcher. Their interest in research might have influenced my approach and interest in their PLT meetings. High school teachers, on the other hand, were not as familiar to me, and I struggled to communicate with them. My dissertation chair helped me to overcome this potential bias and understand the perspectives and contexts of high school teachers. Another bias was about the way teams met. It was much more possible for me to interact with virtual PLTs, because I was not joining them as a stranger. In face-to-face PLTs, my attendance was through a screen, and I was sometimes forgotten in the meeting. To overcome this, I tried to have more interaction with the PLT leaders of those face-to-face PLTs. My attendance in the PLT meetings might have changed or altered the discussed subjects. To avoid this, I tried to develop a trust within the PLTs to be an observer of their lived experiences and then to be able to ask them about these experiences in interviews if they consented to participate. I ensured them that I was not there to evaluate their knowledge. I was just a participant, and as an extra, I was able to answer any questions about the MOOC material or structure.

Organization of Results

As stated before, the goal of a phenomenological research is to describe a lived experience of a phenomenon (Creswell, 2007). To reach this goal, the results for this study are presented in two main chapters. Chapter 4 presents detailed results from the analysis of various data sources described in the previous section. In this chapter, findings from the analysis are

provided to better understand the phenomena of participating in a blended professional

development experience of learning through online materials in a MOOC as well as with

colleagues in a small professional learning team.

       According to Wertz et al. (2011), the analysis for phenomenology (interpretive

phenomenology) should incorporate narrative analysis methodology to make it well suited for

describing the individuals and their experience. Even though narrative methodology is not used

for analysis of data in this study, in Chapter 5, two narrative vignettes are presented for

illustrating the phenomena of engaging in a blended professional development model (online

course and professional learning teams) and impacts of this experience on participants of the

study. Narrative vignettes have long been suggested by qualitative methodologists as a way to

provide both particular and general rich descriptions of an observed phenomena (e.g., Erickson,

1986). To create and present the narrative vignettes for this study, the results presented in

Chapter 4 (detailed results from the analysis of various data sources) were used to construct and

justify the elements used in the narrative vignettes. These vignettes are designed to provide a

representative image of the lived experiences from the perspectives of a PLT leader and a PLT

member.

CHAPTER 4: RESULTS

According to Creswell (2007), phenomenological research attempts to describe the meaning of lived experiences for several individuals and focuses on "describing what all those individuals have in common as they experience a phenomenon" (p. 57). Results will be presented in two sections in this chapter. First, the phenomenon of participating in both a MOOC and PLT (external domains) will be identified. Then this participation in the external domains will be described as a way of establishing opportunities to learn from their experience in these domains. Finally, both what those participants experienced, how they experienced it and the interrelations between these external and personal domains will be examined (domain of practice).

The Phenomenon and The Framework

In Chapter 2, a framework was presented to provide a lens for understanding teachers' growth in aspects of their professional world when engaged in professional development that can be considered as external to that world (Clarke & Hollingsworth, 1999).

Teachers' change or professional growth could occur within each domain separately, or through an action and reflection process. To examine the professional growth of teachers, six constructs were provided as guiding hypotheses in the previous section. However, to answer the research questions of this study, the focus will be on three domains (personal domain, domain of practice, and external domain) and only explore in depth two hypotheses/constructs concerning the impacts one domain may have on another (Construct IV: External Domain >> Domain of practice; and, Construct V: External domain >> Personal domain). All three domains will be examined in the context of this study.

External domain >> Personal domain: I hypothesize that participants' engagement in a MOOC and a PLT influences their knowledge and confidence in teaching statistics. For example,

a teacher explores a conceptual misconception discussed in a MOOC forum and realizes that he/she also has that misconception and tries to overcome it.

External domain >> Domain of practice: I hypothesize that participants' engagement in a MOOC and a PLT influence their teaching statistics practices. For example, as they engage with others in PLT meetings, they may learn about a strategy they individually did not know of before, and they may transfer this new strategy to their class teaching practices.

As seen, three domains are at the center of this study: external domain, personal domain, and domain of practice. The results will begin with rich descriptions of how participants engaged in the external domain, and the foundations of how those things might have affected the participants will be presented in terms of research focus. In Figure 6, the arrows between the domains that are labeled with Roman numerals represent the enactments and reflections between the domains.
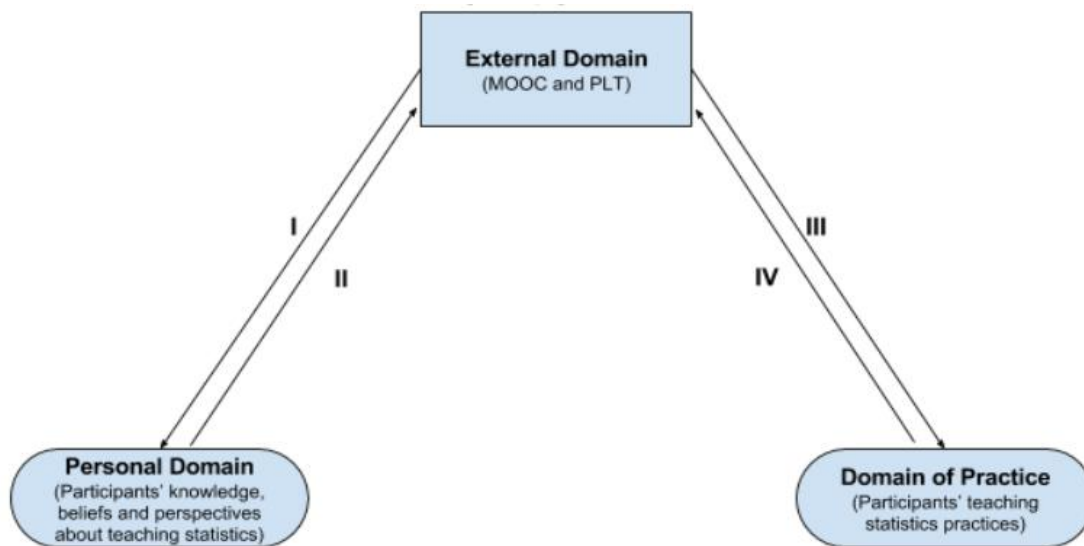
Figure 6. Three domains of focus and lived experiences

<center>**Participation in the External Domain**</center>

The external domain in this research consists of two professional development communities: 1) the large online community within the TSDI MOOC, and 2) the small group community within the PLT. Both MOOC and PLT represent a community 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, 2001). In this study context, the TSDI MOOC and PLT have a shared domain, and that is teaching statistics. The TSDI MOOC is a much larger CoP with much more variability in the contexts of MOOC participants' educational practices than the practices of those in a PLT. On the other hand, PLTs include more practices that are shared by the members of PLT; for example, PLT members actively and purposefully meet and discuss closely what they have recently learned in TSDI MOOC.

It is vital to describe how participation in the external domains (PLT and TSDI MOOC) impacted participants' professional growth. It is important to note that participation in the external domain had different characteristics for different participants. Participation in the external domain occurred completely online for some participants, while others had both online and in-person experiences. This was because the MOOC was an online platform, but PLTs formed and met either online or face-to-face.

Participation in the TSDI MOOC

The context of the TSDI MOOC was explained in the Research Methods section. Here, the detailed information about fall 2016 and spring 2017 MOOCs will be given, particularly focusing on the PLT members. Table 5 presents the demographics of participants in the TSDI MOOC and the subgroup of those that were part of a PLT.

Table 5. *Demographics of TSDI MOOC and PLT participants in 2016-2017*

	TSDI MOOC (N=804)	PLT (n=63)
Gender	63% female / 35% male	75% female / 24% male
Location	80% in the U.S.	100% in the U.S.
Primary focus of enrollee employment	62% classroom teaching	76% classroom teaching
Highest level degree in education	55% MS / 24% PhD	51% MS / 25% PhD
Organization type	43% College/University / 37% Middle/High School	60% College/University 30% Middle/High School
Years of experience	12 years (average)	14 years (average)

The enrollees in the TSDI MOOC consisted of 356 participants in fall 2016 and 489 in spring 2017, for a total of 804 enrollees. As seen in Table 5, the vast majority were from the U.S. (n=633) and the rest (n=166) were from other countries, with the majority being female (63%). Overall, 62% of the enrollees indicated that their primary focus area of employment was classroom teaching (K-12 or college), where 7% chose curriculum and instruction; 6% chose student (college and graduate school); and 6% chose teacher preparation. The participants generally were highly educated, with 55% having a master's degree and 24% a PhD. Enrollees' organization type varied with most located in a college/university (43%) or middle or high schools (37%). Participants' years of experience in teaching also varied. 24% of them had 20 years of experience or more; 19% of the participants had 6-10 years of experience; 19% of the participants had 1-5 years of experience; 18% of the participants had 11-15 years of experience; 16% of the participants had 16-20 years of experience; and the remaining 3% had no experience in teaching.

In total, 63 PLT participants were registered for the MOOC during fall 2016 (n=37) and

spring 2017 (n=29). Three participants enrolled in both semester's courses. As seen in Table 5, all PLT participants were from the U.S., with the majority being female (75%). Overall, 76% of the enrollees 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 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%). Participants' years of experience in teaching also varied. 25% of them had 20 years of experience or more; 18% of the participants had 6-10 years of experience; 24% of the participants had 1-5 years of experience; 14% of the participants had 11-15 years of experience; 13% of the participants had 1-20 years of experience; and the remaining 5% had no experience in teaching.

Among all TSDI MOOC participants, of the 804 registered for the course, 509 actually accessed the course. As seen in Table 6, 87% of those participants viewed at least one resource, 50% of the participants posted to forum discussions, and 14% of them accessed a certificate of completion. Earning a certificate was different from completing the course, though. Completing the course could be defined as accessing Unit 5 (which means that the participant accessed all the units); with this, 23% of the participants completed the course. Among PLT participants, of the 63 registered for the course, 61 participants accessed the course. As seen in Table 6, 97% of those viewed at least one resource, 83% of them participated in forums, and 38% of them earned a completion certificate. 70% have completed the course by accessing material in Unit 5.

Table 6. *MOOC activity of participants who accessed the course in 2016-2017*

	All Participants	Non-PLT	PLT
Viewed at least one resource	87% ($N = 509$)	86% ($n_1 = 448$)	97% ($n_2 = 61$)
Participated in forums	50%	46%	83%
Earned a certificate of completion	14%	11%	38%
Completed the course by engaging in some materials in all 5 units	23%	19%	68%

Participating in a unit is defined as viewing forums, library resources, pages, or web links. The following graph (Figure 7) shows the number of participants engaged in each unit.
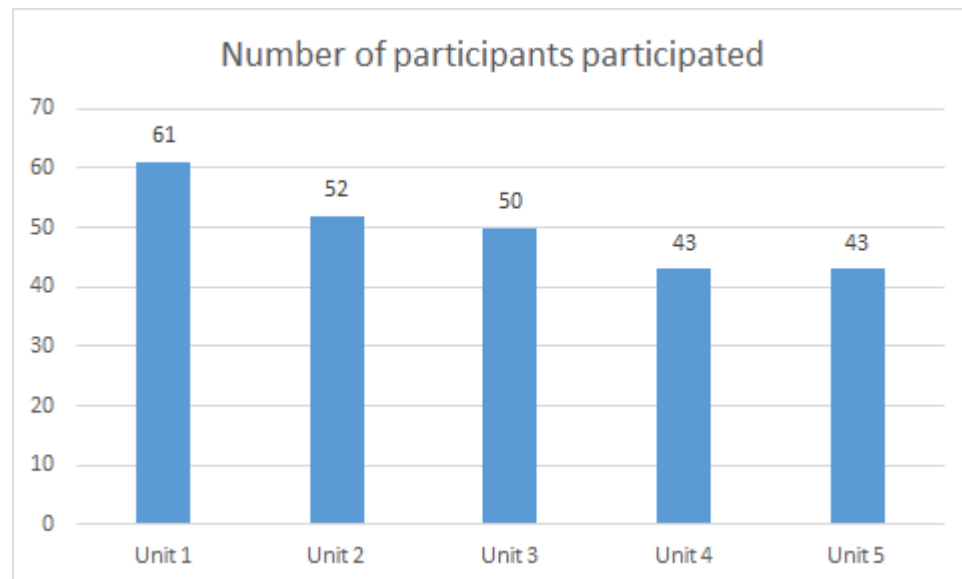
Figure 7. Number of PLT participants who participated in MOOC by unit

Taking a closer look at how the PLT members engaged in resources in the TSDI MOOC, Figure 8 shows the relationship between the number of days a participant entered the course and the number of resources viewed by PLT participants. It is important to note that even though

actual raw log data may show many actions within a day, that could be due to a poor internet

connection or participant's characteristic actions (accessing the MOOC several times in a day but

not accessing many resources on that day), thus, the number of days a participant logged in can

give a sense of the sustained engagement within the MOOC. For many other MOOCs, designers

stated that participants are counted as returning if they have viewed resources for two or more

days. There were only three PLT participants who accessed the course for only one day.
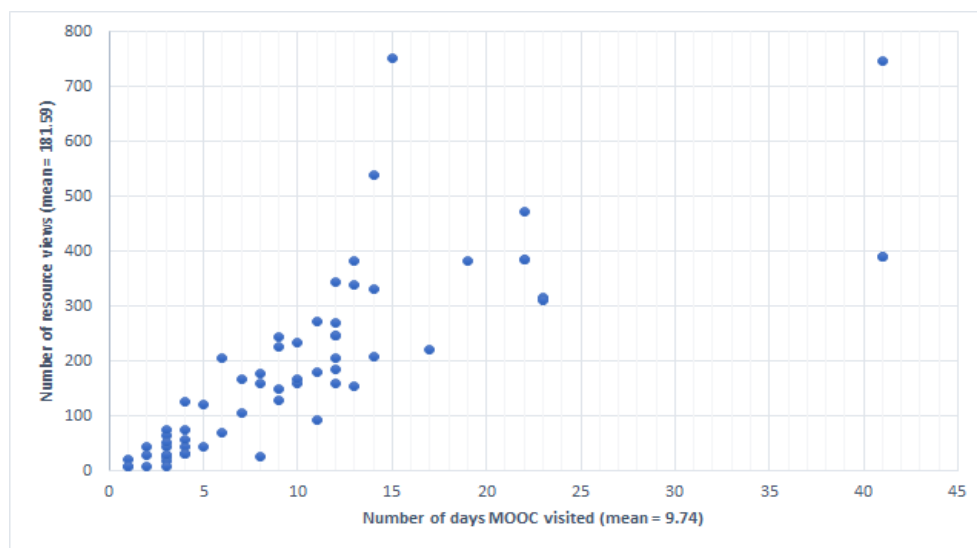
Figure 8. Number of days visited by number of resources viewed by PLT participants

Table 7 illustrates the stark difference between the how PLT members and non-PLT

MOOC participants engaged in the MOOC. These provide strong evidence to say that PLT

participants were richly engaged in TSDI MOOC, and thus they had ample opportunity to learn

from the online external domain. Even though it is not the focus of this study, the comparison

creates a strong case for the differences in engagement in the TSDI MOOC between PLT and

non-PLT participants.

Table 7. *Number of days the MOOC was visited, and resources viewed by participant type*

	NonPLT (N = 448)	PLT (n = 61)
Number of days visited the MOOC (mean value)	3.80 (St.dev. = 3.41)	9.74 (St.dev. = 8.11)
Number of resource views (mean value)	56.4 (St.dev. = 52.24)	181.6 (St.dev. = 166.24)

The TSDI MOOC has 10 discussion pages (forums) in total (two in each unit). Even though the number of PLT members that accessed the course (n=61) is around 1/9 of the total number of all course participants who accessed the course (N=509), most of those 10 discussions included PLT members' entries. There were 212 discussion threads including at least one PLT member's entry. The average number of posts made by a PLT member was 10.84, thus, we could say that on average every PLT member has an entry for every forum discussion. This shows us a very clear picture of how enthusiastic PLT members were to talk to others in the online community and pose their questions and ideas to others about teaching statistics throughout the units, even though they were also meeting with their colleagues in their PLTs.

Participation in the PLTs

As explained previously, in the PLTs, participants and groups assist each other in achieving learning objectives from the TSDI MOOC, as well as making progress toward other goals that a PLT may set for themselves (e.g., improve use of technology in their introductory statistics courses). During fall 2016, all four PLTs were comprised of faculty, instructors, and students in community college and university settings. During spring 2017, all five PLTs were comprised of high school and community college mathematics teachers. Table 8 (Table 1 is repeated here) shows basic information about 9 PLTs in this research.

Table 8. *PLT team information*

Team	Grade/ # / Location	General Description
Team1	Community College / 7 / NC	The team was led by a former MOOC participant. The team consisted of 7 community college teachers from two institutions at NC. 6 members completed the process. 6 meetings were held. Meetings held virtually.
Team2	University / 10 /NY	The team was led by a former MOOC participant. The team consisted of 10 university instructors from the same university at New York. Meetings held face-to-face.
Team3	University / 8 / MI	The team was led by a former MOOC participant. The team consisted 6 university instructors and one graduate student from the same institution at MI. All members completed the process. Meetings held face-to-face. 6 meeting were held.
Team4	University / 10 / NV	The team was led by a former MOOC participant. The team consisted 8 graduate students in an elementary math education department in NV. 6 members completed the process. Meeting were held virtually. 6 meetings were held in total.
Team5	High School / 6 / (Several East coast states)	The team was led by a first time MOOC participant. The team consisted of 6 high school mathematics teachers. All members completed the process. The teachers were a part of a separate project about statistics education and teach in different locations on the east coast. Five meetings were held virtually.
Team6	High School / 6 / HI	The team was led by a first time MOOC participant. The team consisted of 5 high school mathematics teachers teaching at the same private school. All members completed the process. Meetings held face-to-face. 5 meetings were held in total.
Team7	High School / 7 / MI	Former MOOC participant. 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.
Team8	High School /5 / NE	The team was led by a first time MOOC participant. The team consisted of 4 high school teachers teaching at the same public school at Nevada. 2 members completed the process. The 10 meetings were held face-to-face.
Team9	Community College / 4 / NY	The team was led by a first time MOOC participant. At the beginning, the team consisted of 4 community college teachers at the same institution. Only two members completed the process. Meetings held face-to-face. 5 meetings were held in total.

The following paragraphs provide brief descriptions of the participation and experiences in each team.

The leader and two members of Team 1 were very curious about trying new methods in teaching statistics; their discussions about applying new ideas and approaches to their teaching occupied most of the meeting time. Those discussions included some issues about statistical content. For example, a member frequently highlighted the issues she faces while teaching specific statistical content, such as p-value and hypothesis testing. She was open to sharing her difficulties in teaching those subjects, because she stated that the students used to get confused and/or misunderstand those subjects, and that was because the teacher (she) did not understand the subject well. This issue was discussed several times. Because of these discussions, this team pointed out that professional development about conceptual understanding in teaching statistics would be a nice thing for them. A member of this team who brought up the issue of conceptual understanding enrolled for the MOOC in Spring, as well, and she richly engaged in the course.

The leader and one other member in Team 2 were active in the MOOC by participating in forums; others were mostly observers of the course, but they still participated in all PLT meetings. The leader of this team participated in interviews and completed the surveys. As a sociology professor who has been teaching statistics for more than 20 years, she reflected a different perspective about teaching statistics. According to the leader, statistics teaching in social science departments has different problems than other areas. In these departments, statistics is a required course for students, and instructors are mostly from the same department (i.e., a sociology professor in a sociology department teaches statistics or statistical methods). During the PLT meetings, the faculty often discussed how they were not trained to teach statistics. The leader stated that the online tools and methods offered in the course were not

familiar to this team, thus that was a good and interesting learning opportunity for them; however, they expected more college-level emphasis and tools instead.

Unlike the other fall teams, Team 3 included three members (including the leader) that were familiar with the SASI framework and several technology tools introduced in the MOOC. Thus, the meetings had a more advanced level of discussion. The team met on approximately every two weeks on Friday afternoons from the end of September to the end of November. According to the leader, this was a great opportunity for having leadership in the university and communicating with other educators who teach statistics, having discussions about their concerns and practices in teaching statistics, and trying to initiate a positive change in their teaching of statistics. Instead of spending much time discussing the unit materials, this team quickly delved into discussions about their practices. The focus was more about the concerns and technical issues in applying changes to university statistics courses. The meetings usually covered a discussion of what participants learned from the latest unit of TSDI MOOC. In the last meeting, the leader posed a question to the members asking for the most impressive thing they learned in the MOOC. The team agreed upon the concept of real and messy data. They reflected that this was an eye-opening opportunity for them to learn about how learning and engaging with real and messy data is important in statistics. The leader stated that the distinction of messy data was particularly new for most of them. The teacher's role in presenting messy data and cleaning it was something they needed to discuss for hours both during PLT meetings and out of the meetings. Some members were not quite satisfied with the MOOC content, because they thought that it was not very useful for college-level teaching.

Team 4 was a group of students (preservice teachers) in an elementary mathematics education program who took a course about teaching statistics. The PLT leader was also the

instructor of this class and was a PhD student in the same department. The leader was writing her

dissertation on improving in-service math teachers' content knowledge in statistics. She wanted a

deeper understanding of how professional development affects content knowledge, and she

thought that this experience would also contribute to her content knowledge. PLT meetings were

held after the face-to-face course, at the same place where the course was taught. Because team

members were elementary mathematics teachers or teacher candidates, the context of the TSDI

MOOC was difficult for this team to understand well, and in fact, there was no room to apply

what they learned. The members' interest in this experience decreased after the first week of the

MOOC when they found out that the content of the course was not that useful for elementary

mathematics education purposes. In the first meetings, the leader mostly asked questions from

the PLT guide and the members tried to answer those questions. Some discussions naturally

occurred when students did not understand or showed signs of misunderstanding the subjects. In

later meetings, the leader used the online tools provided by TSDI MOOC to present and engage

with elementary level statistics activities. This change worked well and grasped members'

attention again. While presenting activities with online tools, the leader used the SASI

framework. In order to make sure that team members really understood the SASI framework, the

leader wanted the team members to present short activities using the SASI framework during

their last meeting. According to the leader, this worked well, and she was confident that the

members were informed about SASI framework. The leader stated that she had a moment of

revelation when she found that using different teaching strategies or methods was as important as

teacher's content knowledge in teaching statistics.

All members of Team 5 were active high school mathematics teachers from various states

(PA, NJ, VA, NC). The leader had been teaching statistics since the 1990s in high schools and

community colleges. The leader had some experience with PLTs, however this was her first virtual one. The leader, as with other spring PLT leaders, had not participated in the TSDI MOOC before, however she had a strong interest in teaching statistics. She stated that this was a great opportunity to help other teachers and get help from them to understand MOOC content better. The team met through an online conference tool. The leader set and led the discussions, mostly focusing on the last unit the participants had completed. All the meetings were recorded for future use and for members that may miss a meeting. The leader also used an instant chat extension to communicate with members and remind them about their participation. Members of that team knew each other from a workshop about statistics teaching they had previously attended together. Because of this prior group experience about the same subject, the nature of the discussions during the meetings were different from other teams. The members comfortably addressed their previous discussions, and they were more comfortable in communicating issues with each other. After Team 3, this team included the most confident teachers in teaching statistics (according to pre-SETS results). Even though they were confident, it was not clear whether this confidence reflected the right skills and knowledge. Some members were overconfident about their teaching, because they had been teaching statistics for over 20 years, and their overconfidence would possibly represent a resistance to change. The team held five meetings in total. In some of those meetings, time issues in applying the new methods and problems with students' exam requirements were discussed. Because the members were from different school districts, it was possible for them to compare and contrast their teaching conditions with others.

Team 6 followed the PLT guide very carefully, and they seemed eager to learn from this experience. However, three members of this team had little or no experience in teaching

statistics. Thus, other than discussing TSDI MOOC materials and the issues about practicing those materials in teaching in detail, the team spent a lot of time discussing the basic concepts of statistics, such as probability, measures of center, understanding of uncertainty, etc. All five members completed the journey. The leader had been teaching mathematics for more than 25 years, and teaching Advanced Placement(AP) Statistics since 1997. However, the only formal statistics class she had taken was a night course from a university. She stated that she felt very excited to take the TSDI course, and she was interested in recruiting a PLT with other teachers in her school. Team members' statistical background and teaching experience varied. The leader and another member were longtime AP Statistics teachers; two members were mathematics teachers who had never taught statistics before; one member was going to teach a statistics class during next semester. The meetings were focused on MOOC units, and the leader primarily used the questions from the PLT guide to initiate discussions. Using the computer lab of the private school where they work, members had a chance to try technological tools and activities during their meetings. The leader stated that the review of activities and tools in the MOOC and the discussions about them were very beneficial for the members. A problem frequently addressed during meetings was the time constraint in applying new ideas and approaches in teaching statistics.

The leader of Team 7 was curious about and motivated for the experience of leading a team of high school mathematics teachers after leading a team of university faculty. The leader's interest in teaching statistics and understanding these efforts to improve teaching statistics doubled after her experiences in the fall, and she decided to lead this PLT during spring. Her goal for the spring team was championing teaching statistics at the secondary level with the current recommendations instead of earlier, more mathematical recommendations. She wanted to

form the team in her community to support each other, discuss, and apply the recommendations made in the MOOC. The PLT consisted of seven members, including the leader. The meetings were held face-to-face, and the team met in one of the high schools in the district. Each meeting was about a specific unit, and the team conducted five meetings in total. After initial discussion about the unit, they talked about how to apply the new methods in their teaching, what the potential barriers were, etc. At the end of every meeting, the leader gave recommendations to the members, as a teacher educator. This team was very concerned about their content knowledge, and the leader was aware of that. At the end, as with other PLTs, this team's confidence increased. And also, the members realized they needed to improve their content knowledge and teaching skills in statistics.

Team 8 and Team 9 were two teams that did not reflect much on what they learned or how their meetings went. Only the leaders completed the follow-up surveys, and there were no members that chose to participate in interviews. Thus, there is little evidence to describe the participants' journey in these two teams. Team 8 was a team of four high school teachers from the same high school in NE, and according to leader's post-meeting snapshots, they held ten short meetings, mostly after their lunch breaks. Team 9 had four members from the same community college, and according to leader's email, they held five meetings and discussed TSDI MOOC materials. Only two members continued to attend after the first meeting. No more details are known about those two teams. Also, their team members were not as active as others in the TSDI MOOC. As a proof of this inactivity, they were a part of the cluster in the bottom left of the scatterplot in Figure 6, entering the MOOC infrequently and viewing few resources.

Lived Experiences in TSDI MOOC and PLT.

Participants' lived experiences in the MOOC and PLT were analyzed through examining various data sources, such as the pre- and post-SETS survey to measure confidence to teach statistics, forum discussions, MOOC surveys, PLT follow up surveys, MOOC end-of-course survey, and PLT member interviews. Analysis began with the forum discussions. All forum discussion threads that include PLT members' entries were collected as forum discussion data. There were 212 documents (discussion threads) fitting the criteria (thread including at least one post from at least one PLT member). The unit of analysis was the entries of PLT participants. For example, as seen in Figure 9, there was a forum discussion as follows with two non-PLT MOOC participants and two PLT participants; only PLT participants' entries were coded. In this example there are two units of analysis (See Figure 9). Each PLT entry was coded with lived experiences at the same time with no upper limit of codes. For example, an entry could be coded with one or five lived experiences at the same time. The most apparent lived experience observed as existing in an entry or response applied in the first place as a code.
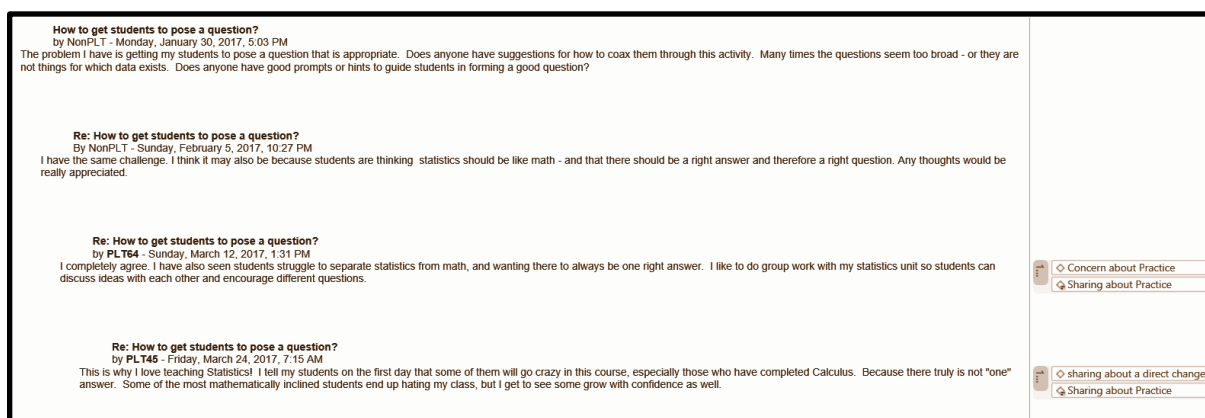
Figure 9. A discussion thread example in Atlas.ti

Just like forum discussions, all qualitative survey data was also analyzed. In survey data, the units of analysis were the responses given to any open-ended question (each response was a

unit of analysis). That survey data included follow up surveys, unit feedback surveys, end-of-course surveys, and post-meeting snapshots (only for leaders).

First, the lived experiences observed in this phenomenon (participating MOOC and PLT) will be presented with brief descriptions and with stories of how they were identified. Then specific changes answering our research questions will be explained.

As described in methods section, coding the qualitative data began with using pre-determined TSDI MOOC elements that had been previously shown to trigger shifts in perspectives about teaching statistics as codes. Those elements were SASI framework, technology, real and messy data, and videos. The first plan was to confirm those triggering MOOC elements and find potential new elements either in the MOOC or the PLT, if possible. The study design is phenomenology, and in phenomenology, the lived experiences are at the center of study. For example, instead of including real and messy data as a code, learning about and engaging with real & messy data was used to indicate instances of a lived experience using that course element in the external domain. Thus, the adapted elements are transformed to actions within the context; they are, now, the lived experiences in the phenomenon. Besides coding for evidence of lived experiences related to engagement with MOOC elements, an open-coding was also conducted in order to seek understanding of other lived experiences in the phenomenon. For example, sharing about practice emerged as a strong idea related to change in beliefs and perspectives; thus, it was noted as a lived experience that impacted teachers' professional growth.

In order to give a sense of the coding process, we could use specific data sources. End-of-course surveys were part of the TSDI MOOC, and they included questions related to the research focus of this study. Thirty-four PLT participants took the end-of-course survey. The first

100

question of this survey is: "How effective was this MOOC-Ed in supporting your personal and professional learning goals?" Thirty-three participants responded this question and 91% of them chose either effective or very effective. Another question of the end-of-course survey was: "What was the most valuable aspect of this MOOC-Ed in supporting your personal or professional learning goals?" Twenty-six participants responded to this open-ended question. Those responses are coded with the lived experiences in this phenomenon. Some answers helped to expand codes. For example, observing videos was a code at the beginning; when the following response to the above question was read, it was decided to expand that code into two new codes: "I really loved the expert panel discussions!" According to this response, the video element of the MOOC was used separately for students' videos and expert panel videos; thus, there should be two lived experiences: one for observing practices from the videos, and was another for listening and reflecting upon expert panels.

The following is the resulting list of the most dominant shared lived experiences observed during the qualitative data coding:

- Learning about and applying the SASI framework;

- Learning about and engaging with real and messy data;

- Learning about and engaging with technology;

- Observing practices from videos;

- Listening and reflecting upon expert panel discussions;

- Sharing about personal practices;

- Unpacking MOOC materials;

- Encouraging each other to progress;

- Being concerned about content or practice

As it will be explained later; those lived experiences participants engaged in in the external domain influenced changes in the personal domain and the domain of practice. First, those lived experiences will be explained in more detail and information about how those were developed for both the MOOC and PLT will be given. Then, it will be described how those lived experiences were developed from coding, and how codes were expanded and refined as these were the most critical and most prominent lived experiences that came out of data sources.

Learning about and applying SASI framework

Students approaches to statistical investigations (SASI) framework is at the heart of the TSDI MOOC course and it offers a radically new method for teaching statistics through data investigations (including four phases of data investigations: posing a statistical question, collecting data, analyzing data, and interpreting results, as well as attending statistical habits of mind). As a TSDI MOOC element, SASI framework was previously found to trigger the shift in perspective that engaging in statistics should include the use of the investigative cycle and statistical habits of mind (Lee, Lovett & Mojica, 2017). This study attempted to confirm whether this impact still exists. Participants' responses to survey questions and in discussion forums have shown that this MOOC element continues to be a strong component that triggers a change in teachers' perspectives about teaching statistics, as well as their teaching practices. In the coding process, the learning and applying of the SASI framework code appeared 229 times in all qualitative data.

Learning about and engaging with real and messy data

As a TSDI MOOC element, real and messy data was found to trigger a change (towards the shift: engaging statistics requires real and messy data) in teaching statistics (Avineri, 2016). This study attempted to confirm whether this impact still exists. Just like SASI framework, real

and messy data was new for most of the participants, which they discovered by taking the course and participating the PLT. The lived experience form of this element is named learning about and engaging with real and messy data. Most of the units coded with this experience reflected participants' learning of and appreciation for real and messy data. During interviews, participants expressed their appreciation of learning more about this, and their realization of the importance of real and messy data. Most of them stated that they planned to change their choice of data from ready-to-use and clean to real and messy data that students collect and clean. The experience was documented 92 times.

Learning about and engaging with technology

Technology is a TSDI MOOC element which is related to a change (towards the shift: engaging statistics is enhanced using dynamic technology) in teaching statistics (Avineri, 2016). This study attempted to confirm whether this impact still exists. Participants seemed to gain strong benefits from the technology tools provided and explained in the TSDI MOOC. Also, PLT meetings contributed to a better learning of those tools. The lived experience was named learning about and engaging with technology. The code was applied when an entry or response included realization of the importance of integrating technology in teaching statistics, or an emphasis about the technology tools included/presented in the external domain. The code was applied 149 times during qualitative coding.

Observing practices from videos

The videos of teachers and students conducting statistical activities in TSDI MOOC were found as a trigger of a change in teachers' perspectives about teaching statistics and teaching statistics practices. In forum discussions, the videos of teachers and students were discussed often. Also, in post-surveys, participants reflected that those videos were very useful to give a

sense of how to apply the newly learned methods in classrooms. Some participants suggested the course should include more videos and perhaps lessons. The code was applied 72 times during analysis.

Listening and reflecting upon expert panels

The expert panel videos in TSDI MOOC were found to trigger a change in teachers' perspectives about teaching statistics and teaching statistics practices. Those videos were placed at the beginning of every TSDI MOOC unit to give an introduction about the subject. Four faculty members that are experts in statistics or statistics education discussed specific subjects or methods and a recording of those discussions was added to the TSDI MOOC. Participants particularly mentioned this lived experience in their forum discussions, post-survey responses, and interviews. Listening and reflecting upon expert panels seemed informative for participants to help them understand more about the concepts/methods presented in the course. In PLT meetings, those panel discussions were the focus of the meetings many times. The code was applied 28 times.

Sharing about personal practice

This lived experience is primarily found in the PLT domain as sharing was more direct and a primary action for the participants. This experience is about participants' sharing about their past, current, and possible future experiences in teaching statistics; reacting to the experiences shared by others; and making and sharing plans for their own practice. Participants heavily appreciated the opportunity to listen to their colleagues' experiences about teaching statistics and sharing their own experiences to get feedback from others to improve their own teaching skills. TSDI MOOC (with forum discussions) and PLT provided this opportunity for

them, and the direct relation between this lived experience and the tendency for change was obvious. This was the most frequent code used during the analysis; it was applied 440 times.

Unpacking MOOC materials

This lived experience represents the efforts to discuss the MOOC materials with colleagues to make sense (or more sense) of them. PLTs mostly met after each TSDI MOOC unit, thus unpacking the course materials was one of main actions in those meetings. It included sharing with colleagues about their perspective of MOOC related materials, attempting to explain MOOC materials to others, and asking questions about the material to understand MOOC materials more fully. By unpacking MOOC materials, participants did not ignore the things they learned through participating the MOOC. The code was applied 143 times during the analysis.

Encouraging each other to progress

Being encouraged by the intense sharing with colleagues and understanding MOOC materials better, participants provided evidence of a desire to continue to learn and grow in teaching statistics. The data showed that most of the members felt enthusiastic about continuing to learn about TSDI and apply it to their actual teaching practice. PLT made this theme more apparent with a sense of community or perseverance. In domain of practice, encouraging each other to progress helped the participants finish the MOOC and reflect that they could do it. The code was applied 122 times during analysis.

Being concerned about content or practice

In their forum entries and survey responses, participants showed concerns about the statistical content or about teaching practices, and those concerns seemed to impact the way they dealt with what they learned through PDs and the possible changes in their practices. Those

concerns could be about the time limitations or curriculum requirements, or sometimes could be due to a lack of knowledge or conceptual understanding. Some teacher participants expressed fear of a radical change in practice, because the students could be negatively impacted by this change. Teacher participants mostly did not feel free enough to change their teaching; this was either because of the physical limitations (limited access to technology, time constraint, etc.) or because of a lack of confidence to change. The lived experience was used as a secondary code most of the time (when the unit was already coded with other experiences, and an expression of concern has taken place). The code was used 325 times during analysis.

A Closer Look at Lived Experiences from Follow Up Data

The lived experiences presented in the previous section were from all qualitative data in the study. To illustrate the presence of these lived experiences, I present a closer look at how dominant these lived experiences were when PLT members and leaders reflected on their overall experiences in this blended professional development. The two primary sources of data used here to illustrate this are the follow up survey sent several weeks after the conclusion of the course, and interviews done several months after the course.

Each open-ended response to the follow up survey questions was coded for qualitative analysis; each response was considered a unit of analysis. The most frequent code applied to follow up surveys alone was sharing about practice (40 times) then encouraging each other to progress (30 times). The following quotes illustrate examples coded with those two lived experiences.

> "I met with individuals from nearby schools and learned their approach to the course. They also encouraged me to try these approaches and share my experiences. I felt I saw good examples on statistics practice (i.e. labs), and I have made modifications to how I conduct my class as a result." (PLT member, fall 2016, six years of experience)

"It was interesting to hear the ideas from the other participants in person instead of just reading the discussions online. It also gave me deadlines to keep moving forward in the course." (PLT member, fall 2016, 22 years of experience)

As described earlier, both lived experiences were primarily related to the PLT. Other lived experiences encountered during coding follow up surveys with the number of times used are as follows: learning about and applying SASI framework (18); learning about and engaging with technology (13); learning about and engaging with real and messy data (5); unpacking MOOC materials (9); listening and reflecting on expert panels (3). It is important to note that, while follow up surveys were built to investigate both MOOC and PLT experiences in the external domain, both sharing about practices and encouraging each other to progress were considered as primarily coming from PLT, and they were the most frequent lived experiences used during coding. As it will be further discussed in the next section, PLT is found to be an effective complementary part of the efforts to provide a MOOC to positively impact teachers' professional growth in teaching statistics

Consenting PLT members were asked to participate in interviews about their experiences and how they impacted their teaching perspectives and practices. Thirteen interviews (seven with PLT leaders and six with PLT members) were conducted. Interviews were conducted virtually, and each lasted approximately 45 minutes. Each response to an interview question was coded with the nine lived experiences described above. Each response was considered a unit of analysis, and the lived experiences were applied as codes during the coding process. The most frequent lived experiences applied to interview data were learning about and applying SASI framework and sharing about practice; both lived experience codes were applied 47 times.

The following interview response was coded with two lived experiences: learning about and applying SASI framework and learning about and engaging with real and messy data.

> Question: "Describe a few things you learned about teaching statistics throughout your experiences as a PLT leader."
>
> Answer: So, something that came out, something I learned, something I haven't done a lot, the idea of working with messy data sets that have multivariate… data cleaning, organizing. I liked the idea using this with my students. I haven't taught stats after that experience yet, next time I would like to use that. Continuing emphasize of SASI framework was another thing I will use." (PLT leader, spring 2017, 24 years of experience)

The Impacts on Personal Domain and Domain of Practice

According to Clarke (1994), effective PD programs recognize that "change is a process, not an event; the individual must be the primary focus of interventions; and change is a highly personal process" (p. 39). Research suggests that PD programs that engage participants in identifying their own goals have a positive impact on teachers' practice (Clarke, 1994; Hawley & Valli, 1999; Avineri, 2016).

As explained before, the impacts or changes in personal domain and the domain of practice were the products of enactments and reflections between those two domains and the external domain. Participants' lived experiences in the external domain seem to influence the impacts or changes that will be explained in detail. One or more lived experiences in the external domain are examined to see how they influenced the participant's knowledge, beliefs, and perspectives about statistics, and/or how it changed the way the participant teaches statistics. The data sources used to support the claims about those impacts were participants' forum entries in the MOOC, things said during PLT meetings, and their own reflection on their overall experience in their survey or their interview responses.

As they will be described and explained in detail with supporting evidence from the data, here are the list of the impacts observed:

- Impact 1: Gaining confidence in teaching statistics;

- Impact 2: Increasing instructional repertoire for teaching statistics;

- Impact 3: Changing goals for teaching statistics;

- Impact 4: Developing a commitment to continue learning skills to teach statistics;

- Impact 5: Willingness to try new ideas and approaches in teaching statistics;

- Impact 6: Limiting potential professional growth

Impact 1: Gaining confidence in teaching statistics

The increase in participants' confidence to teach statistics will be examined by analyzing SETS results and other qualitative data.

Self-Efficacy for Teaching Statistics (SETS) survey measures participants' confidence in teaching statistics. All MOOC participants could take the surveys in the orientation unit and again in the final unit of the course, but that was not a requirement for earning a completion certificate. After matching pre- and post-surveys, 28 PLT participants took both the pre- and post-SETS. There were 44 Likert-scale questions and one open-ended question in SETS.

A dependent samples t-test was used to determine whether there was an increase in participants' gain scores in confidence to teach statistics after their participation in the course and PLT. The prompts in the SETS questionnaire are separated into three blocks, and each block represents different GAISE levels of sophistication (A, B, or C). The first 11 items of the SETS survey represent Level A, following 15 items represent Level B, and the last 18 items represent

Level C. The analysis is conducted for every sub-scaled score of these different levels and for the total.

Since a paired t-test is a parametric test with an assumption of normality, the distribution of gain scores for the total confidence score (postTotalSETS-preTotalSETS) should be checked for normality. Using Wessa's (2017) online tool, a Normal QQ Plot was created with the total SETS gain scores, which indicated the distribution was somewhat normal (See Figure 10). The assumption of normality was then assessed via Kolmogorov-Smirnov (K-S) test, and the results suggested that normality was a reasonable assumption for our data set. For example, the K-S test for total SETS gain scores had a test statistic value of .1546. Larger values of the K-S test statistic indicate the distribution does not follow a normal distribution. Since .1546 < .2499 (K-S test critical value for α=.05), the data is a reasonably good fit with the normal distribution, and a paired t-test can be used.
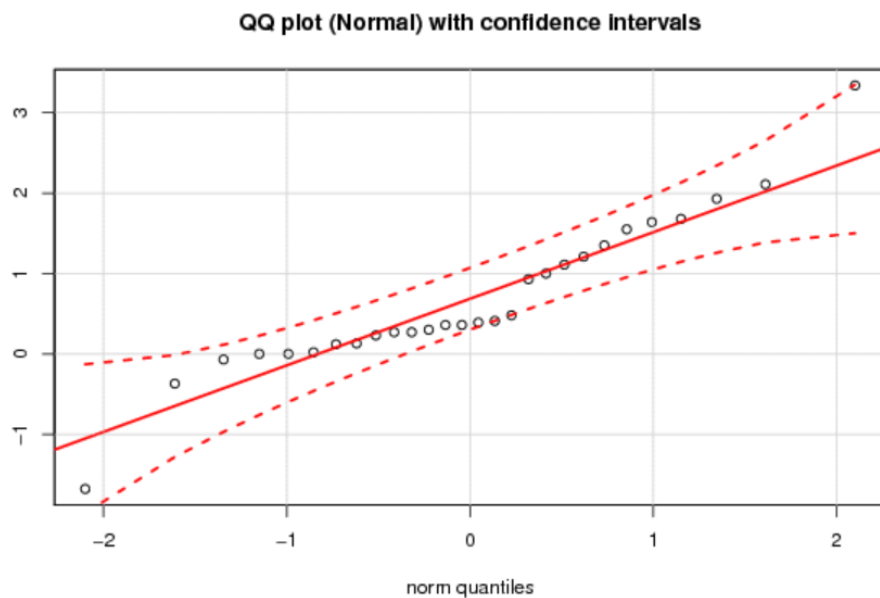
Figure 10. Normal QQ plot

Table 9 represents the SETS survey data for 28 PLT participants that completed both the pre- and post-SETS instrument.

Table 9. *PLT participants' SETS results*

	Pre-SETS Mean	Post-SETS Mean	Difference Mean	Standard Deviation	t-test
Level A Scaled[a]	4.19	4.82	.63	.90	3.71***
Level B Scaled[a]	3.87	4.63	.75	1.06	3.76***
Level C Scaled	3.83	4.48	.65	1.05	3.30***
Total Scaled[a]	3.93	4.62	.68	.96	3.77*

Note. $N = 28$.
[a]Scaled to 1-6.
*$p < .05$, **$p < .01$, ***$p < .001$.

The question being asked for this analysis is: Is there sufficient evidence to suggest that PLT and MOOC participants' confidence in teaching statistics was increased after they took the TSDI MOOC and they participated in PLT? In other words, is there sufficient evidence to suggest that the mean score is greater for the post-SETS than the pre-SETS?

Ho: There is no difference between post and pre-SETS test scores. Md=M2-M1=0

Ha: M2>M1

Total Scaled Scores: The 28 participants had an average difference from pre-test to post-test SETS scores of .68 (SD=.96), indicating the participation resulted in a significant increase in confidence to teach statistics; $t(27) = 3.77$, $p =< .001$.

Level A Scaled Scores: The 28 participants had an average difference from pre-test to post-test Level A SETS scores of .63 (SD=.90), indicating the participation resulted in a significant increase in confidence to teach statistics for Level A; t (27) = 3.71, p =<.001.

Level B Scaled Scores: The 28 participants had an average difference from pre-test to post-test Level B SETS scores of .75 (SD=1.06), indicating the participation resulted in a significant increase in confidence to teach statistics for Level B; t (27) = 3.76, p = <.001.

Level C Scaled Scores: The 28 participants had an average difference from pre-test to post-test Level C SETS scores of .65 (SD=1.05), indicating the participation resulted in a significant increase in confidence to teach statistics for Level C; t (27) = 3.30, p=<.05. (Note that increase in Level C was lower than in Levels A and B.)

Thus, we reject the null hypothesis and conclude that there is sufficient evidence to say that participants' confidence to teach statistics was increased by this phenomenon (participating in both PDs). As a conclusion of looking to quantitative data of SETS results, we could claim that after participating in both MOOC and PLT PD projects, the PLT participants' confidence to teach statistics increased.

At the end of the pre-SETS survey, participants answered a similar question with minor differences. The open-ended question in pre-SETS was as follows:

"Consider some of the topics that you were most or least confident teaching. What may be some reasons that teachers might be more or less confident in teaching those topics?"

In the end post-SETS survey, participants were expected to answer the following open-ended question:

"Consider some of the topics that you were most or least confident teaching. Did anything we did in this MOOC help you gain confidence in those areas? For the areas you are still less confident with, what may help build your confidence?"

Our desire is to figure out whether there was a change in answering this question after participating in the MOOC and the PLT. Table 10 provides a sample of four PLT members' responses to the open-ended questions.

Table 10. *SETS open-ended response examples*

Term / Years of Experience	Pre-SETS	Post-SETS
Fall / 9	I've only rarely taught about fitting data to models.	The concept of sample vs. population and the ideas around variability are two areas that I find are greatly improved using some of the real-time examples and simulations from this MOOC.
Fall / 1	I feel like I do not have enough practice or knowledge about these topics to be able to teach them to my students.	I am more confident in creating experiments and gathering data. I feel like I could have used more help in analyzing the data.
Spring / 5	Teachers might be more or less confident in teaching certain topics due to experience and education background.	Being able to talk with others and play with data helped me to gain confidence in those areas. The whole idea of exploration really helped me to gain confidence. I think having resources and activities with the activities I am less confident in would help me to gain confidence.
Spring / 27	As math teachers, we probably feel more confident with topics that involve calculations and less confident about topics that involve things that can limit the conclusions of those calculations, such as lurking variables and weaknesses in the data collection techniques.	I gained confidence in the technology end of things by reviewing some of the resources (that are bookmarked, but I do not recall their names off of the top of my head) presented in this course.

As seen in the table above, these four participants reflected on the change in their confidence in their own words. For example, a fall participant with one year of experience answered the question saying that he or she did not have enough experience or knowledge; on the other hand, the post-survey response of this participant included a detailed description of the impact stating that he or she had gained confidence in creating experiments and collecting data. The teacher directly reflects on the change in his or her confidence in conducting a statistics lesson using SASI framework.

The participant on the fourth row stated that math teachers used to feel more confident in more 'mathematical' subjects, and statistics is not one of those. In the post-survey, the participant said that she or he gained confidence in using technological tools. As a teacher with 27 years of experience, that participant gives a good sense about the strong connection between confidence to teach statistics and being able to use technology for teaching.

There were 15 participants (out of 28 who took both pre- and post-SETS survey) who gave us evidence of self-reflection on the positive change in their confidence to teach statistics. Knowing that the post-SETS was taken after TSDI MOOC and most of the PLT meetings were completed and looking at both participants' SETS quantitative results and open-ended responses, coding for participants' lived experiences indicated that learning about and applying SASI framework, learning about and engaging with real and messy data, learning about and engaging with technology, sharing about practice, and encouraging each other to progress helped them to gain confidence in teaching statistics.

A response given to a question in the end-of-course survey ("What was the most valuable aspect of this MOOC-Ed in supporting your personal or professional learning goals?") also showed evidence supporting increased confidence after participating in MOOC and PLT.

"This course gave me some great lesson plan ideas. It also made me more confident in teaching statistics where before I felt like I knew nothing about teaching statistics. After this course, I feel like I would teach it to my students." (PLT member, 8 years of experience)

This shows a strong sign of how the lived experience encouraging each other to progress impacted the personal domain by increasing the confidence of the participant. The participant seemed like she / he was inspired by attending the MOOC and PLT; such an inspiration that, in a few months' time, it changes the participant's response from "I knew nothing about teaching statistics" to "I feel like I would teach it to my students."

Increase in confidence to teach statistics was also observed in forum discussions in the MOOC.

"Through this course I have gained confidence in teaching statistics. I am constantly looking for new ways to present material to my students to help them understand statistics. This course has given me numerous teaching aides to assist my students in learning the concepts."
(Forum discussions, Unit 5, Spring 2017, High School, Face-to-face, 6 years)

"This course has given me the desire to teach statistics. I can see how it would be a great tool for working with those "not good at math" types of students. Those students really need to be motivated by seeing how things apply to the world and from this course, I can really see how that could be accomplished."
(Forum discussions, Unit 5, Spring 2017, High School, Virtual, 12 years)

Impact 2: Increasing instructional repertoire for teaching statistics

The lived experiences sharing about practice, observing practices from the videos, and unpacking MOOC materials helped the participants to increase their instructional repertoire for teaching statistics. Several pieces of evidence from qualitative data sources supported this claim.

For both semesters, participants were asked to fill out follow up surveys about their participation. The survey included several questions about participants' self-reflection on their

experience in this phenomenon. The questions asked, and a summary of responses, may give a sense of the results:

"Question 1: As a result of your participation in this MOOC-Ed and PLC meetings, did you acquire any knowledge, skills, and/or resources applicable to your professional practice?"

Including seven PLT leaders and 15 PLT members, all 22 participants' answer to this question was "yes." The participants were also asked to explain their response for the first question. Let's look at a response for this question:

"It got me thinking more about starting everything off with data and questions and focusing more on the concepts rather than the skill/drill." (PLT Leader, 27 years of experience)

The above example shows the direct impact of the TSDI MOOC and the lived experience learning about and applying SASI framework into the participant's perspective about teaching statistics. As a 27-year experienced teacher, the participant points to a radical change: "starting everything off with data and questions." Even though further study is needed to claim whether this impact will also take place in the domain of practice, we can at least say that there is a potential for a change in the domain of practice for this participant.

Another answer given to the question was:

"I met with individuals from nearby schools and learned their approach to the course. I felt I saw good examples on statistics practice (i.e. labs). I have made modifications to how I conduct my class as a result." (PLT member, 7 years of experience)

This response from a teacher participant shows the impact of PLT on the participant's personal and professional practice (from the participant's self-report). By sharing about practice with colleagues from nearby schools, the teacher made changes in her/his practice. In this

example, sharing about practice helped the participant to enrich their teaching practice with good examples and modify it.

During the interviews, a PLT member gave the following response when she was asked how she found PLT meetings influencing the MOOC experience:

> "The small group meetings were great to understand what we learned in the MOOC. I mean, sometimes, some stuff we learned did not make sense at the time. For example I did not understand how census at school could be used in the class; during our meeting, this was discussed, and I tried that in my class the following week. It was great!" (PLT member, 4 years of experience)

In the above example, the participant's response shows that the lived experience unpacking MOOC materials during the PLT meetings helped the participant to understand MOOC materials better and encouraged the participant to use that material in his/her class.

Impact 3: Changing the goals for teaching statistics

The lived experiences learning about and applying SASI framework, and learning about and engaging with real and messy data changed participants' goals for teaching statistics. By learning about and applying SASI framework, participants saw the importance of posing a statistical question and collecting the data. Several participants advocated that they used to attend only to the analyze data and interpret results phases of statistical investigation in their teaching. Also, by the lived experience learning about and engaging with real and messy data, participants realized the importance of what data is used and the teacher's role in cleaning it. Several examples supported these claims.

In the interviews, there was a specific question about the participants' impression of the PLT. For this question, most participants' responses included traces of sharing about practice. As

in the following example, the responses mostly showed that these experiences were positive for their personal and professional learning, and might influence their practices positively in the future.

> "It was more about discussions. Some members had more experiences in teaching stats, some like me did not have. Some shared their experiences, labs; it was very helpful to learn from others. That was nice to hear other teachers' issues and how they struggle and overcome those issues. It was great to discuss what we learned from the MOOC, and how we could use these learning in our teaching practices."
>
> (PLT member interviews, Fall 2016, Community College, Virtual, 9 years)

Learning about and applying SASI framework was the most popular experience found in TSDI MOOC. Even though it is not in the curriculum, some participants mentioned this lived experience as a new teaching objective when they were asked to give feedback on MOOC materials. They changed their priorities in teaching statistics.

> "I work with college students taking introductory statistics. It is the same in my classes. I really thought the data sets from Census at Schools would be a great way to get them interested. Using that we could build on their skills and getting them into a "statistical habit of mind". By the way, I never included such thing in my agenda before.
>
> (PLT member interview, Fall 2016, Unit 5, Face-to-face, University, 0 years)

In the above example, participant states that using an online source (Census at School) provided in the MOOC is a great way to achieve a goal set by the course: building statistical habits of mind-. This example shows that the lived experience learning about and applying SASI framework impacted the domain of practice (plans about teaching are considered in the domain of practice) by becoming an objective for statistics lessons.

A question in the end-of-course survey was: "To what extent do you agree with the following statements?" (statements were about the course objectives, such as understanding of how to engage students in statistical investigation processes). These were Likert-scale questions

and could be answered from strongly disagree to strongly agree. The average rank for this question

was 4.35, which shows a strong sign about a positive impact on participants' understanding of the

course objectives from their own-reflections. When the participants were asked how effective they

felt this MOOC was in preparing them to make positive changes in their professional practice,

91% of the participants chose effective or very effective. Another question was: "Have you made

any changes in your professional practice as a result of your participation in this MOOC?" 79% of

the participants responded yes; 3% responded no; and the rest (13%) responded not sure. As seen,

the majority of the participants self-reported that they made changes in their practice as a result of

this experience.

Another change was that participants saw the importance of posing a statistical question

and collecting the data phases related to the lived experience learning about and applying SASI

framework. Before this experience, some participants stated that they used to attend to only the

analyze data and interpret results phases of statistical investigation process. The following

examples show evidence of this impact.

> "I have started posing questions before each task that I assign the students. I really think
> this is the area I need to improve on the most. I love that mantra "developing statistical
> habits of mind."
> > (End-of-course survey, Fall 2016, Face-to-face, University, 15 years)

> "I have embraced the investigative cycle and try to make this the focus of my course to
> explain why we are doing what we are doing. It has changed how I structure things and
> when I teach topics. I realized that I used to attend only analyze data and interpret results
> phases, and skip pose question and collect data phases. This will definitely change!"
> > (PLT member interview, Fall 2016, High School,
> > Virtual, 8 years)

The lived experience learning about and engaging with real and messy data was very

popular in participants' responses to survey and interview questions. Just as SASI framework,

real and messy data was a new idea that teachers realized the importance of. The impact is that

by learning about and engaging with real and messy data, participants realized the importance of

what data is used and the teacher's role in cleaning it. The following examples present this

impact.

> "The one thing really really striked me was the use of real and messy data. The kids used
> to get the data very unrealistically clean and just ready. My way of teaching will change
> in this sense. Dealing with messy data, opened my eyes to just leave it like that."
> (PLT member interviews, Spring 2017, High School, Face-to-face, 22 years)

> "The MOOC made me more excited to use real data instead of just textbook data. The
> areas in which I am not confident are mostly due to the length of time since I studied
> them. A review of the concepts is what I would need. Easily done when needed."
> (SETS open-ended, Fall 2016, University, 12 years)

Impact 4: Developing a commitment to continue learning and skills to teach statistics

The lived experience encouraging each other to progress was helpful to motivate the

teacher for developing better statistics teaching abilities. Encouraging each other to progress

developed a professional sense in participants to pay more attention to their teaching and a

commitment to continue learning and applying new approaches. Also, the lived experience being

concerned about content or practice encouraged teachers to pay more attention to the subject they

teach and develop their knowledge and teaching skills.

Participants became more curious about new approaches and wanting to learn more about

those, and they developed a commitment to continue learning about teaching statistics. The lived

experience that triggered this impact was encouraging each other to progress. This lived

experience is related to personal domain and the change is that the participants became more

curious and wanted to learn more after this lived experience. By encouraging each other, the

participants became more curious about new approaches and wanted to learn more about them.

This experience triggered a professional sense in participants. They learned that paying attention

to their teaching statistics is important and they developed a commitment to continue learning

and applying new approaches. The participants also gained the feeling of "I can do this!" The

following examples provide evidence of this impact:

> "This course has given me the desire to teach statistics. I can see how it would be great tool for working with those "not good at math" types of students. Those students really need to be motivated by seeing how things apply to the world and from this course, I can really see how that could be accomplished."
>
> (Forum discussions, Unit 5, Spring 2017, High School, Face-to-face, 6 years)

> "I certainly intend to watch for future enrichment courses! I feel that every time I sat down to explore through the material, my enthusiasm for teaching statistics was reinvigorated. Thank you so much for that!"
>
> (PLT member interview, Spring 2017, High School, Face-to-face, 12 years)

Participants tried these different approaches (using SASI framework and promoting

habits of mind; using more technology; using real and messy data) in their actual practice and

they self-reported this direct impact (from those who taught after participation). The following

examples of data provide evidence about these direct impacts in the domain of practice.

> "I also like how real this data set is for the students. Last term, I gave my students a google form to answer questions, similar to the census at school, and I was able to see the "messy" data that was entered, but it is also good for them to see and decided what to do with the data."
>
> (Forum discussions, Unit 5, Spring 2017, High School, Face-to-face, 6 years)

> "I am using real data more and am trying to spend more time with the pose and collect phases rather than just the analyze and interpret phases."
>
> (End-of-course surveys, Fall 2016, University, Face-to-face, 12 years)

Being concerned about content or practice gave participants the sense of "I need to develop myself; I need to continuously work on it." This lived experience influenced the participants' comfort and changed their over-comfortableness. Feeling overwhelmed with the actual burden of teaching statistics and not having enough understanding of the subject (impact in personal domain) triggered teachers to pay more attention to the subject and develop their knowledge and teaching skills. The following examples provide evidence of this impact.

> "Helping me recognize what it takes to teach statistics well, so that I can keep a realistic mind-set when lesson planning. The course I currently teach only allows a few weeks for statistics, so this gave me a sense of the "bigger picture" in terms of what I want to focus on or de-emphasize to make the biggest impact on student learning & understanding of statistics."
>
> (End-of-course survey, Spring 2017, Face-to-face, High School, 8 years)

> "One thing was that it reemphasized how statistical thinking really different from mathematics. I was frustrated about how we need to be more creative about stats; following only a book was not the right to do. Teaching stats actually adds more burden, creativity to teacher. Investigation cycle was very important; it was what statistics is really about. If you leave things a little open-ended, it takes more time for the class, so it was frustrating, you do not have much control; you are bounded with requirements. So, I thought a lot about how to do things in a right way. I was looking for something to plug in easily; but the resources were too many; so instead of getting an easy thing to use, is ready, I got the reality of stats and its actual requirements, I got new questions then; what difference between stats and data science is."
>
> (PLT member interview, Spring 2017, Face-to-face, High School, 28 years)

The following interview response to the question about their reflection on the overall experiences they had in the external domain tells us how encouraging each other to progress was helpful to motivate the teacher for developing better statistics teaching abilities.

> "I am looking forward to the second course this summer. I have gained confidence but one thing I find even more valuable is a gain in motivation; motivation to create and implement a great statistics course with the investigative cycle."
>
> (PLT member interview, Spring 2017, High School, Face-to-face, 8 years)

Impact 5: Willingness to try new ideas and approaches in teaching statistics

The lived experiences learning about and engaging with real and messy data and learning about and applying SASI framework gave participants a willingness to try new ideas and approaches. Also, learning about and engaging with technology created a willingness to share new technological tools within professional communities. Another two lived experiences, observing practices from videos and listening and reflecting upon expert panel discussions, helped participants make more sense of the three lived experiences listed here (learning about and applying SASI framework, learning about and engaging with real and messy data, and learning about and engaging with technology). Thus, all five lived experiences were effective in building this impact of willingness to try new ideas and approaches in teaching statistics.

Through various data sources, changes in personal domain and the domain of practice were observed. For example, according to qualitative data, a willingness to try new approaches and the openness that participants need to try new approaches to teach statistics were clear (for those who did not teach after they participated). This impact was particularly related to newly learned elements about teaching statistics through TSDI MOOC (real and messy data, promoting habits of mind, attending pose and collect phases). The following examples show evidence of this impact:

> "I am so thankful that I took this mooc. I have enjoyed it immensely. The resources given here have given me so many ideas to try. But I think first and foremost I need to review the way I teach the material. I don't think I have done a good job in the past in really exploring the investigative cycle with my students. This is where I want to begin to improve; making sure they and I are developing those "statistical habits of mind". I feel like the rest will improve with time. I already do technology in the classroom-statcrunch-but could use it more. I want to be asking better questions and hopefully seeing my students emulate that."

> (Forum discussions, Fall 2016, Face-to-face, University, 12 years)

"My colleague and I have discussed having all students in a math class do the census at school and then having our students pull from this data and other data sets within that site."

(End-of-course surveys, Spring 2017, Virtual, High School, 9 years)

"...I feel inspired to learn more about how to improve the way I teach this class. To begin, I plan on "posing questions" in a better way. I feel that this is the area I need to improve the most."

(Forum discussions, Fall 2016, Virtual, Community College, 8 years)

Observing practices from the videos was another lived experience found to directly influence teachers' beliefs and perspectives about teaching statistics. The impact was that, by observing practices from the videos, participants got a sense of how to apply the SASI framework, real and messy data, and integrating dynamic technology to teaching statistics. The following example provides evidence about this impact.

"I thought the videos from other countries was informative. At first, I was laughing to myself thinking of how my students would never be that involved or ask such deep questions. However, after completing this MOOC, I believe that if we can introduce statistics at an earlier age and help them grow, then yes, it is possible to have students ask deeper questions.
Unfortunately, it won't happen overnight, but it was very inspiring to watch."

(Forum discussion, Fall 2016, Virtual, Community College, 6 years)

A question in the follow-up survey was the following: "Have you applied any knowledge, skills, and/or resources acquired through your participation in the MOOC-Ed and PLC meetings to your professional practice?"

Among leaders, six answered 'yes' for this question, and only one leader answered no. Among PLT members, there were six yes; seven no; and two not sure responses. Those who answered no for this question mostly stated that they had had no opportunity to teach statistics after taking the course.

> "Yes. There have been one or two lesson ideas that I have already tried out with my students and I will be sharing those ideas at AP Stat workshops this summer." (PLT Leader)

In the above response, the participant mentions a direct impact in the domain of practice. The participant tried some ideas in his/her class. Furthermore, the participant is willing to share those ideas (probably the ideas presented/learned in MOOC) in a professional workshop.

> "Yes. I modified tasks throughout the semester based on what I learned." (PLT Member)

Again, here is evidence of the impact of the external domain on the domain of practice. We do not have any idea about the results of that impact, though. We only know that the tasks learned in the MOOC are used in practice. The following three examples show no impact for the participant, because the participants stated that they had not yet taught statistics after their participation.

> "Not sure. I am not currently teaching statistics, but my frame of mind is probably different. That has to have an effect on my teaching whether I can put my finger on an actual change or not." (PLT Member)
>
> "No. Not yet, the timing of the course was towards the end of my school year and ap review. I plan to in the fall." (PLT Leader)
>
> "No. I am not teaching introductory statistics this year." (PLT Member)

Impact 6: Limiting potential professional growth in teaching statistics

The lived experience being concerned about content or practice limited the potential professional growth of some teachers by creating boundaries in applying changes in their practice. While most participants gave positive feedback on their overall experience, the experience being concern about content or practice was also observed 36 times. The following response example shows how the concerns about content or practice impacted the domain of practice.

"One thing was that it reemphasized how statistical thinking really different from mathematics. I was frustrated about how we need to be more creative about stats; following only a book was not the right to do. Teaching stats actually adds more burden, creativity to teacher. Investigation cycle was very important; it was what statistics is really about. If you leave things a little open-ended, it takes more time for the class, so it was frustrating, you do not have much control; you are bounded with requirements. So I thought a lot about how to do things in a right way. I was looking for something to plug in easily; but the resources were too many; so instead of getting an easy thing to use, is ready, I got the reality of stats and its actual requirements, I got new questions hen; what difference between stats and data science is."

(PLT leader interview, Spring 2017, Virtual, High School, 18 years)

The above example shows a concern about content. Another concern observed was more about the limitations teachers and students have. The following example shows how the participant is concerned about the mismatch between these rich teaching methods (learned from TSDI MOOC) and the current requirements for teachers and students:

"I learned a lot about teaching stats for myself, also I learned how hard it is to change other teachers' practices. It helped me to criticize the current US system; the standardized test; the questions in the test are very basic and very mathematical. So, it is hard to make teachers take this method more seriously. It does not look practical for them, when students don't need it that much for the test. They have AP stats, but it is not a part of the requirement; only students very good in Math can take that course. We talked about potential changes in this system, but unsure. Our members were unsure about their knowledge in stats. My teachers felt insecure when they saw this radical different approach to teach. They didn't like the idea of not having the actual skills to teach stats if these were the ones."

(PLT leader interviews, Spring 2017, University, Face-to-face, 22 years)

Both examples show that the lived experience being concerned about content or practice could limit the potential professional growth of a teacher by creating boundaries between the external domain and personal domain, and also between the external domain and domain of practice. This experience could slow down changes in practice. On the other hand, the strong

stake sharing about practice has among lived experiences (it was the most frequent lived experience applied as a code during coding) may compensate for this potential negative impact.

Connections between Lived Experiences and the Impacts: The Themes

Looking across all impacts and the lived experiences that seem related to those impacts, several themes emerged. A theme is defined as the relationship between lived experiences and changes (impacts) for this study. In the previous section, those relationships were partially discussed; this section will attempt to situate the relationships found between lived experiences and impacts explicitly within the framework. Figure 11 represents how each of the lived experiences seems to be connected to each of the impacts.

Lived Experiences

Impacts

Learning about and applying SASI framework

Learning about and engaging with real and messy data

Learning about and engaging with technology

Observing practices from videos

Listening and reflecting upon expert panel discussions

Sharing about personal practices

Encouragement to progress

Unpacking MOOC materials

Being concerned about content or practice

Gaining confidence in teaching statistics

Increasing instructional repertoire for teaching statistics

Changing goals for teaching statistics

Developing a commitment to continue learning and skills to teach statistics

Willingness to try new ideas and approaches in teaching statistics
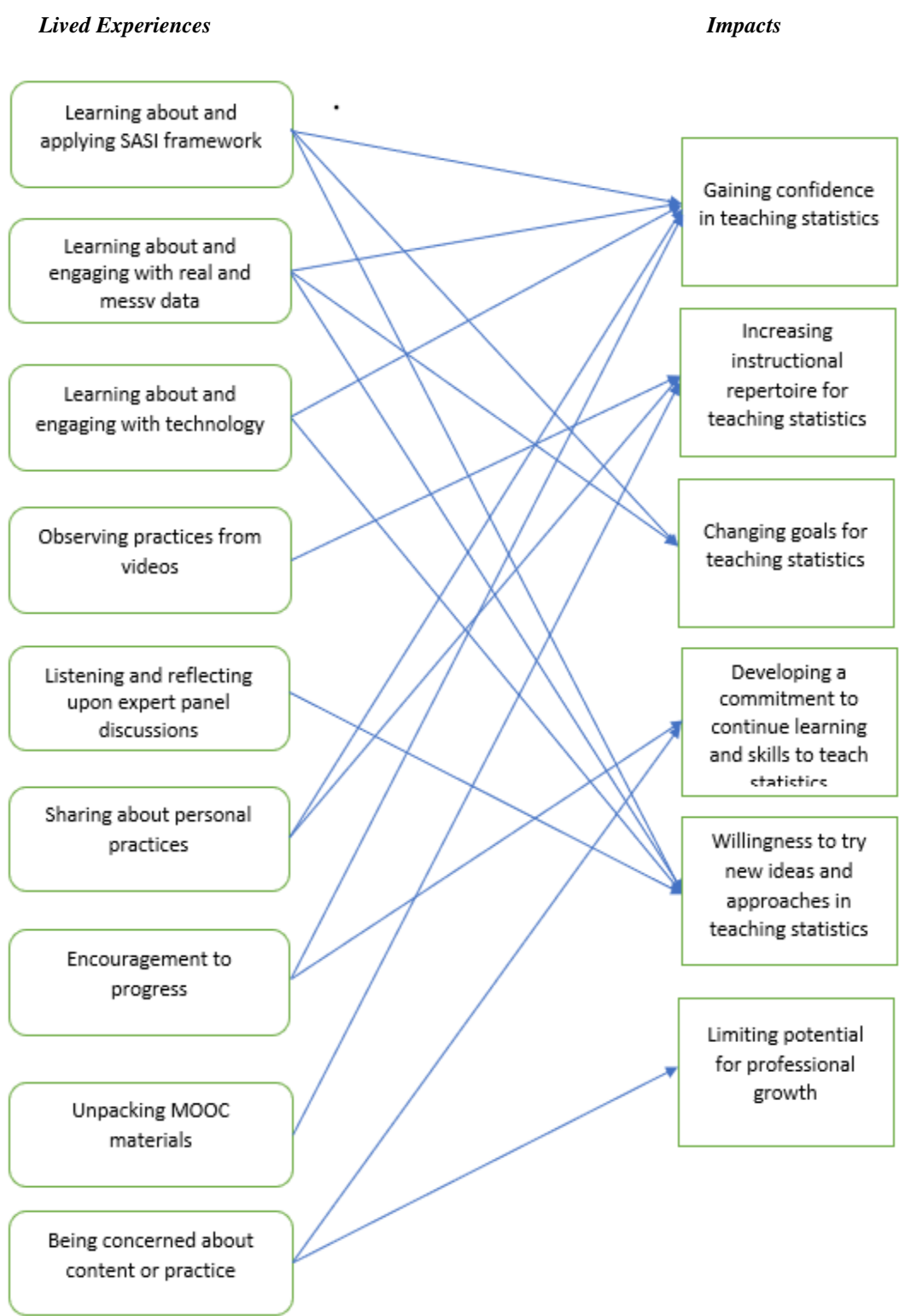
Limiting potential for professional growth

Figure 11. The relationships between lived experiences and impacts

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The diagram of research framework that includes those impacts shown below. As seen in Figure 12, the impacts were either between the external domain and personal domain, or between the external domain and domain of practice. Additionally, there seem to be relationships between impacts as well. For example, Impact 1 (Increase in confidence to teach statistics) may influence Impact 4 (Willingness to try new ideas and approaches). However, there is no clear evidence to support this claim, or other possible relationships between the impacts.
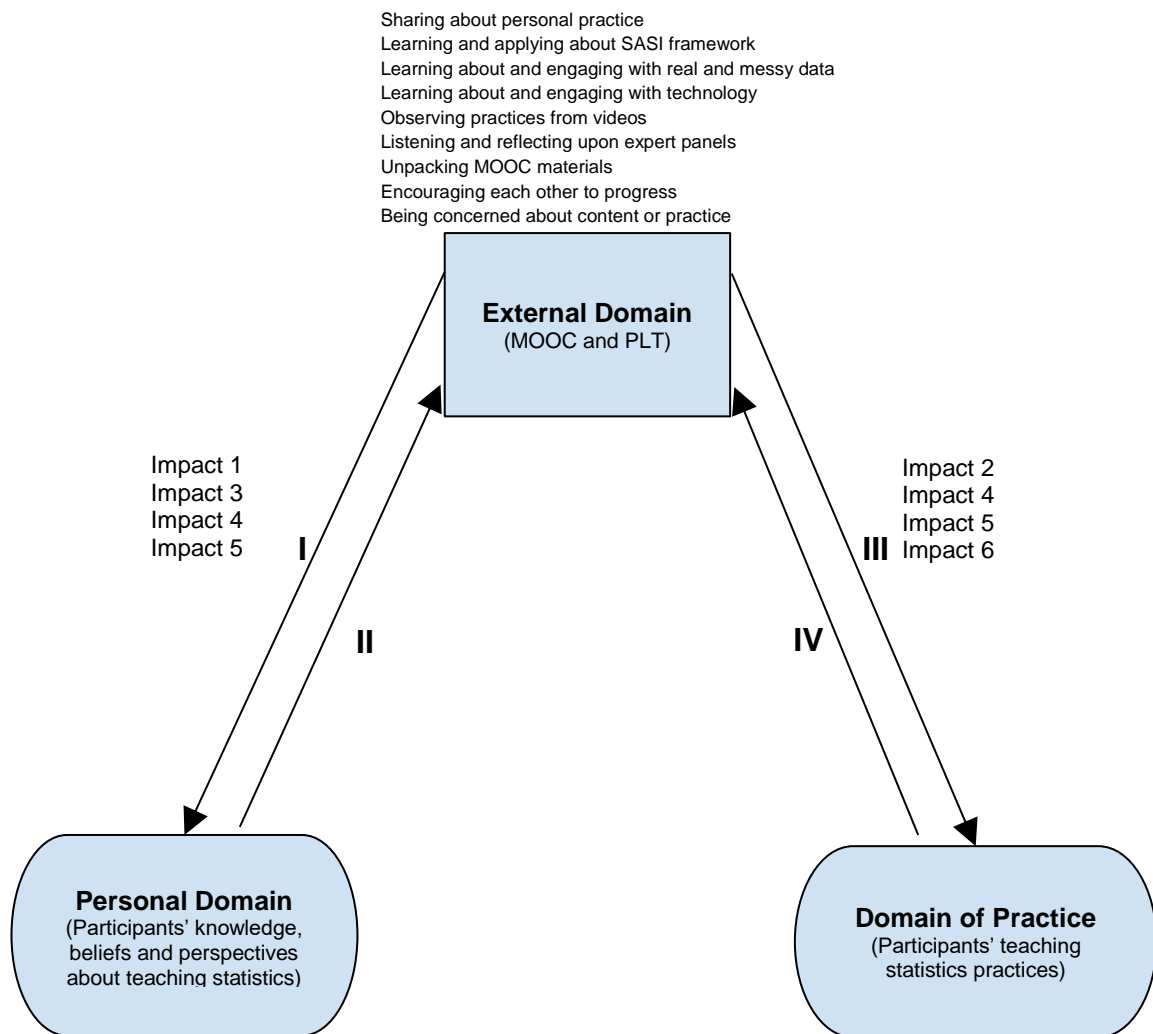
Sharing about personal practice
Learning and applying about SASI framework
Learning about and engaging with real and messy data
Learning about and engaging with technology
Observing practices from videos
Listening and reflecting upon expert panels
Unpacking MOOC materials
Encouraging each other to progress
Being concerned about content or practice

External Domain
(MOOC and PLT)

Impact 1
Impact 3
Impact 4
Impact 5   I

II

Impact 2
Impact 4
Impact 5
III Impact 6

IV

Personal Domain
(Participants' knowledge, beliefs and perspectives about teaching statistics)

Domain of Practice
(Participants' teaching statistics practices)

Figure 12. Research framework with lived experiences and impacts

Sharing about practice and encouraging each other to progress were very effective in triggering the changes in the relationship between two external domains (MOOC and PLT); and between the external domain and the other two domains (personal domain and domain of practice). By sharing about practice primarily through PLT meetings, participants were more motivated to finish the MOOC and they were more actively learning the course objectives. For example, in TSDI MOOC forum discussions, PLT members were enthusiastic in talking and posing their questions to others about teaching statistics throughout the semester, even though they were meeting with their colleagues in their PLTs. Their participation in forum discussions was enormous, compared to non-PLT MOOC participants. Also, sharing about practice helped participants (especially teacher participants) enrich their teaching practices by trying the experiences shared by their colleagues, and even modify their classes based on what they learned from those experiences they heard about and discussed. Other teachers' methods to overcome issues in teaching statistics impacted other teachers to modify and improve their classes.

Learning about and applying the SASI framework, learning about and engaging with real and messy data, and learning about and engaging with technology made participants realize how important those experiences are, and those experiences became teaching objectives for some participants. Participants emphasized several tasks to use to reach those objectives. Those three lived experiences (learning about and applying SASI framework, learning about and engaging with real and messy data, learning about and engaging with technology) also created a willingness to try new ideas and approaches in teaching statistics. Participants realized the importance of posing questions, collecting data, engaging with real and messy data, and engaging with dynamic technology, and they developed a commitment to integrate those ideas into their teaching.

Encouraging each other to progress motivated teachers to be more curious and want to learn more about teaching statistics after this overall participation. This first impact was in their personal domain. This lived experience also impacted participants' domains of practice; it gave participants the professional sense to pay attention to their teaching of statistics and it encouraged them to develop a commitment to continue learning about teaching statistics and apply new methods to their teaching.

Being concerned about content and practice was related to two very different impacts. First, this lived experience limited participants' potential for change. Participants were seen as scared of influencing their students' learning negatively. Sometimes this fear was due to the mismatch between students' requirements about statistics according to curriculum; or it was sometimes due to a lack of resources in dynamic technology, or due to time constraints. Thus, on one hand, this lived experience slowed down the change in teaching statistics practices. On the other hand, being concerned about content and practice also triggered the participants' need for self-learning to be a better teacher. Some participants claimed that they were very comfortable about teaching statistics at the beginning. As they proceeded to learn about and engage with course elements and listen to others' experiences, they had these concerns about their own background and skills, and these concerns encouraged them to improve themselves. Additionally, it is important to note that the relationship between the lived experience being concerned about content and practice and the impact limiting potential growth was observed differently across different contexts (teaching in high school, community college, or university). The types of concerns that were brought up by PLT members from different contexts, or the ways in which they were limited in their growth differed. While a high school teacher was concerned about time constraints and he or she found it very difficult to apply the changes

recommended in the MOOC because of those time constraints, a university faculty member was more concerned about the gap between the MOOC content (tasks, activities, etc.) and the level to which he or she should apply the changes (e.g. university level introduction to statistics course).

Participating in the MOOC and PLT increased participants' confidence to teach statistics. Most of the teachers went from a "I know nothing about teaching statistics," or "I am clueless about statistics myself, how could I teach it?" level, to an "I can do it!" level.

It is found that the PLT is a great complementary project to reach the course objectives set for TSDI MOOC. By several lived experiences, sharing about practice, unpacking MOOC materials, and encouraging each other to progress, participants became more confident to finish the MOOC. Instead of ignoring or forgetting less-understood content in the MOOC, they were able to discuss with their team members and learn it. Unfortunately, there was no assessment to evaluate their understanding of MOOC materials, thus there is no evidence to say that they all learned those elements. However, from their self-reports we could say that there were signs to make this claim.

In the next section, two vignettes (a PLT leader vignette, and a PLT member vignette) will be presented to provide a closer look to understand what it meant to be a part of this phenomenon of a blended professional development.

CHAPTER 5: NARRATIVE VIGNETTES

Introduction and Outline

According to Wertz et al. (2011), the analysis for phenomenology (interpretive phenomenology) should incorporate narrative analysis methodology to make it well suited for describing individuals and their experience. Thus, as stated earlier in the Methods chapter, this chapter will present two narrative vignettes to illustrate the phenomena of engaging in a blended professional development model (online course and professional learning team) and the impacts of this experience on participants of the study. To do that, the results from the previous chapter will be used to construct the interpretive vignettes. In doing this, the lived experiences and impacts described earlier will be more viable and they will make more sense by being represented in vignettes.

Selection of the main characters to include in these vignettes should be explained. Even though the story characters seem to reflect a specific PLT leader and a specific PLT member, it is important to note that these characters are fictional. For the leader vignette, most of the story was inspired by a specific leader's experience; however, some parts of that vignette came from other leaders' self-reported reflections. The composite of other leaders' experiences was integrated to represent what it was like to be a PLT leader. On the other hand, the PLT member vignette was fully inspired by a particular PLT member's experiences. However, lived experiences from another member's interview responses within the same PLT with that first member were used to provide more details of the lived experience within that PLT and its impact.

In the previous chapter, participants' lived experiences within the phenomenon of engaging in a MOOC and a PLT about teaching statistics (external domain), and the impacts of

those lived experiences in their personal domain and domain of practice were presented and discussed.

In this chapter, throughout the vignettes, references will be made to each lived experience and the impacts using acronyms as shown in Table 11. For example, when a series of sentences ends with "(LE-1; LE-2; I-5)", it will mean that in that part of the story, the narrative provided an illustration related to lived experiences 1 and 2 and impact 5.

Table 11. *Lived experiences and impacts*

Lived Experience	Impacts
LE-1: Learning about and applying the SASI framework	I-1: Gaining confidence in teaching statistics
LE-2: Learning about and engaging with real and messy data	I-2: Increasing instructional repertoire for teaching statistics
LE-3: Learning about and engaging with technology	I-3: Changing goals for teaching statistics
LE-4: Observing practices from videos	I-4: Developing a commitment to continue learning and skills to teach statistics
LE-5: Listening and reflecting upon expert panel discussions	I-5: Willingness to try new ideas and approaches in teaching statistics
LE-6: Sharing about personal practices	I-6: Limiting potential professional growth
LE-7: Unpacking MOOC materials	
LE-8: Encouraging each other to progress	
LE-9: Being concerned about content or practice	

PLT Leader Vignette

The following narrative vignette is an account of Sophie's experiences as a PLT leader. The story is based on the data collected from PLT meeting notes, MOOC course surveys, PLT leader snapshots, PLT follow up survey, MOOC forum discussions, and the PLT leader interview. Additional characters (representing Sophie's PLT members) will be woven into the

story for the purpose of illustrating specific experiences a PLT leader has in engaging their group members. All names are pseudonyms.

Sophie's world

Sophie is a college-level faculty member and an experienced teacher of statistics. She has participated in several professional development teams before, focusing on revisions in curriculum for pre-calculus courses. Sophie is very curious about and has research experience in statistics education. She has collaborated with several other mathematics education and statistics faculty. She is currently teaching statistics, and she is also involved in teaching teachers about teaching statistics through courses for teachers. She is very enthusiastic about developing her statistics teaching skills and learning about new methods in the field, as well as helping others to better teach statistics. She is eager to use the GAISE framework recommendations and dynamic technology in her teaching. She stated that the main reasons for her participation in the MOOC were her curiosity and motivation. When former MOOC participants were invited to participate in this blended professional development project, she responded right away, and showed an interest in being a team leader.

Sophie's contributions to the data sources provided various evidence. Both Sophie's personal journey and her PLT story will be presented within a narrative inquiry where her perspectives on different ideas will be illustrated through the lived experiences and impacts presented in the previous chapter. She thought that leading a PLT focusing on teaching statistics was a great opportunity both for her and for her colleagues, a great way to be aware of others' efforts in using teaching statistics strategies and discuss best ways to initiate change in teaching statistics.

Setting the scene

To set the scene for our story, Sophie is sitting in her office preparing for the post-project interview. She is taking journal-like notes about how she started this experience, how she formed a team and conducted five meetings, traced her team members' engagements in the MOOC, and encouraged them to benefit as much as they could from this experience. The following vignette is an account of Sophie's experiences, feelings, and perceptions leading to this day.

Waiting for the interview

I just arrived home. School was chaotic today with all the end-of-year requirements. When the sun is here after a long and frustrating winter, it is difficult to get focused. But it is what it is, and summer vacation is soon! I need to prepare for my interview about my recent experiences leading a PLT with my colleagues who worked together to complete the TSDI MOOC. I need to remember what I did in the fall before the interview begins.

It started in August, while I was feeling to the opposite of how I feel right now: full of energy and motivated to do numerous things to improve my teaching and my students' learning. I received an email asking if I was interested in participating in a project called "Networked MOOC-Ed." If I did, basically, I needed to form a local team of 3-10 people taking the TSDI MOOC during the fall and conduct meetings together regarding our experiences in the TSDI MOOC and about our statistics teaching concerns and practices. It sounded wonderful! So, I made a plan.

In the past several years, I have had several discussions with my colleagues in the university about how it is difficult to find a systemic and right way to teach an introduction to statistics. All those discussions were either during our lunch breaks or in instant chats between two or three people at most. This idea of getting a formal team together to discuss this while all

are taking the MOOC was perfect. By the way, I remember taking the TSDI MOOC before and I loved it. It really helped me to learn about different tools and resources to use in my teaching, and more importantly I learned about that SASI framework. Last year, I talked about this experience and some of my colleagues showed a willingness to enroll in the course. So, I reached out to other statistics instructors from the mathematics, statistics, and business departments to invite them to join my team. I realized that two of them had already enrolled in the course, and another four were easily convinced to enroll. They all liked the idea. Finally, my team consisted of eight members including myself and my graduate teaching assistant.

Initial engagements

Since I had taken the TSDI MOOC before, I was not expecting to engage in the course a lot. However, knowing that I would lead a team of seven MOOC participants, I felt a responsibility to log in, to make sure that I knew the materials, and to see how my team members were doing in the MOOC. Seeing their engagement was only possible through forum discussions. Thus, I found myself checking the forum discussions almost every day to see whether my members wrote anything. In the first forum discussions, participants introduced themselves. The introductions were open to others' comments. It was a good opportunity to learn about the diversity of the community of practice.

Our initial PLT meeting was in a conference room in our department. I planned to let everybody introduce themselves first. Even though we were in the same university, not everyone knew each other. In their introductions, I wanted my team members to describe their experience with statistics and MOOCs, to explain why they were interested in participating in this PLT, and what they were expecting to get out of this experience (LE-6). After introductions, I planned to talk about our group goals and make a debrief. I took notes about my members' introductions:

- Vera has been teaching statistics for a long time, mostly theoretical classes but wants to teach more applied classes in the future. She is very new to the technology tools that were presented but is very interested in learning some of them. Her goal for participating in this MOOC is to become a better teacher and figure out what students are learning in her classes.

- Kate teaches theoretical and applied classes. She likes using R and Excel and has been using online textbooks because that is the current trend. She loves being able to use open source materials. She also has a lot of experience with technology and is very familiar with some of the tech tools. Her goal for participating is to learn something new, as there is always something new to learn.

- Alan teaches several statistics and statistics-related classes. His goal for participating is to get some good ideas about teaching statistics.

- Benna has very little statistics experience. She does not like statistics, but her goal is to learn to appreciate statistics a little more in preparation for teaching it in the future.

- Sophie has a long history with statistics. She has taken this MOOC before and is participating in a leadership role to facilitate the PLT environment. Her goal is to lead the PLC and help create a rich environment for the group to learn.

- Rosanne is a new instructor. Her goals are to become a better teacher, get stronger with the technology, and to learn more.

- Julia is a graduate student. Her goals are to become better with the technology tools, to grow a greater love for statistics, and to learn about teaching statistics.

After introducing ourselves, we talked about some group goals. We had to submit this to the project leaders after our first meeting. We came up with four clear goals to work toward:

1. Introduction packet for new/adjunct/graduate professors to help facilitate a better first experience.

2. New activities to help make the classes more fun for both the instructors and students.

3. Look at our statistics curriculum through the lens of this MOOC. Are there any strategies that we can use to enrich our statistics courses?

4. Explore technology options. Is there something that we can put together that can be differentiated for the different courses we offer?

After agreeing upon the group goals, we talked about our future meetings. As a group we decided that Fridays were the best days for meetings and always at the same time. There are five units in the MOOC, so we needed five more meetings over the next 11 weeks

Unit 1 included nice resources about the differences between mathematics and statistics, and Jane's Age activity was a part of this unit. Forum discussions mostly included the issues about students' understanding of statistics, curriculum issues, and the issues about teaching practices in statistics. Students' readiness for statistics was discussed and I was involved in that discussion. College level statistics lessons usually deal with this problem. Students come from their high school with minimal engagement with statistics and data analysis and we usually must start reviewing the basics. This creates both a time constraint and frustration for teachers because they are not primarily educated to teach the basics in statistics. High school statistics curriculum needs revisions; that idea was shared by many participants in the MOOC, including my team

members. Another interesting discussion point was the importance of real world applications in statistics. While it is essential for teaching the subject, it is also a problematic thing, because it could lead to some misconceptions in students' minds (LE-9; I-6). I was much more motivated to lead the PLT after these rich discussions (LE-6; I-4).

In the second PLT meeting we talked about Unit 1, and a few big ideas that I wanted to hit. Also, Jim joined our PLC and was at the meeting; welcome! Our first topic of this meeting was about how to get students excited about statistics (LE-6). This is an ongoing issue in statistics classrooms (LE-9). We discussed ways in which we could get students excited about learning statistics, including watching a clip of the Ted Talk by Hans Rosling.

Technology occupied part of our discussion (LE-3). Gapminder (which is the tool presented in Hans Rosling's talk and presented in the first unit of the MOOC) has interdisciplinary uses and can help students to become more interested in statistics with their motion charts (LE-4; LE-7). It presents a visual representation of data that you can watch change over time. Alan also expressed that Google Sheets does something similar with a motion chart. JMP also does some interesting graphical representations, and it is free on our university computers and costs $10 per year for students using their own computers.

Julia talked about Significance Magazine from American Statistical Association (ASA) (LE-6). We found out that the magazine has a lot of good short articles on different types of data that can help connect students to real world examples. Alan said that other MOOC participants were discussing the idea of gathering data through a survey in the MOOC forums. He suggested that it may be good to collect data from students in a survey. Having them use their own information may give them a stronger connection to the data that they are being asked to work with as well. Learning about the magazine, the discussion about using real data, and the thought

of encouraging students to collect their own data were great points made on that meeting (LE-1; LE-2).

We also talked about the highlights of Unit 1 in the MOOC. Benna mentioned how much she loved the different ways of thinking about the Age of Jane question (see appendix). We also talked about assessments, using LOCUS as a pre- and post-assessment tool, as well as AP Statistics exams (the multiple choice test items are released every four years and the free response items every year). LOCUS also has a professional development website available. We also discussed looking at the common core standards for statistics to see what students should know before entering college statistics classrooms (LE-7).

Several concerns were also brought up. In thinking about the Age of Jane question, we discussed how it is difficult to get out of the mindset of being told what to do and encourage students to take the reins and have ownership of their thinking and process (LE-7; LE-9). We have to work on how to make students feel comfortable taking the driver's seat from the very beginning. Having a good foundation will help them go in the right direction when exploring on their own, but how do we address the right way to do things while allowing for that creativity?

We also talked about priority setting in our syllabi. How do we incorporate the new things we're seeing into our classes? We need to adjust what we are doing and not act as if students have not seen any statistics before. The need to focus on developing a conceptual understanding of statistics in students' minds rather than teaching only computations was also discussed (I-3).

We briefly talked about project-based learning. I have several contacts who work with setting up project-based learning at the K-12 level and I will approach them to ask about ideas at the college level that they may have and report back (LE-6).

I shared our takeaways from this with members in a brief email, including the idea that using LOCUS as a pretest to help drive what is being taught in class, our discussion about the use of data sheets/surveys in class, and a way to anonymize these surveys so that the data sets can be used without any extra work (LE-7). I believe that at the end of this second meeting, all members felt grateful for participating in this PLT, just like me (I-2).

The shine of sharing

The second unit of the MOOC was about engaging in statistics. The unit took a closer look at what engaging in statistics means. The differences between mathematics and statistics, the statistical investigation cycle, and statistical habits of mind were discussed in research articles and in expert panel discussion. The videos of actual teachers engaging students in a statistical investigation provided a great learning opportunity (LE-4)! I think, as students do, teachers understand better when they watch real examples of the new teaching strategies. I started to think that videos could be very useful in professional development. Many colleagues prefer more comfortable ways to learn. Not only are they comfortable, but by seeing how the theoretical information could be used, they could feel more secure, knowing that the new method is doable. In this unit, we analyzed mathematical and statistical tasks, and we learned about and engaged with online tools for data exploration (LE-3).

In forum discussions, the tasks we analyzed were discussed. Participants posted about their favorite tasks, and the discussions were mainly about those tasks.

For the third meeting, all PLT members were present in the room. A researcher from the project team joined our meeting virtually to observe and answer potential questions about the MOOC and told us a bit about his dissertation.

I have prepared some questions to pose at this meeting. One of these questions was: "Can you have students simulate data to match a study using a rendered sample from someplace?" I was wondering whether my colleagues could share a way to do this. Alan presented some ideas, but others did not seem experienced in it. Alan told us about how he used the Flint, Michigan lead data in class. It was wonderful to hear how an important real-world issue could be used in class (LE-6; I-5). We asked Alan to share the Flint lead data with us and he did that right away; he emailed everybody in the team the data.

Several important comments were made during the meeting. Julia said that we should not just be presenting numbers with no context. She also added that we could not just do analysis or interpretation; we need to show how to do the other parts of the investigative cycle or how to gather information from the data. Everybody in the room agreed with her. This was the core of Unit 1 and 2. I believe that my team members have already started to get something from this whole experience. Benna said that medical examples are a great way to engage students as they are easy to understand. I added politics and economics examples. Alan pointed out that our students should make their decisions on what they are doing during a statistical task. I said that the more experience students have to critically think, the better.

The statistics task guide presented in Unit 2 seemed too long for us, but it brought up a valuable point: we often do not see the why in the task we use or why a learning objective is being learned in statistics. And, students do not seem to understand the variability component in measurement: what do we do when they reach their limitations (LE-6)? Several concerns arose, such as students will memorize steps instead of applying the appropriate steps for a situation (LE-9; I-6). I cannot remember my learning of statistics at the very beginning as a teacher candidate. Did my professors warn me about these things? Anyway, during this meeting we also

talked about data-first approach textbooks, several were mentioned by different members, such as *Workshop Statistics* by Rossman and Chance; *Introduction to Statistical Investigations* by Tintle, Chance, Cobb, Rossman, Roy, Swanson, and VanderStoep; and, *Statistical Sleuths* by Ramsey.

We also discussed the pros and cons so far with the MOOC, especially with unit 2. My colleagues stated that DreamWorks/Pixar data was really nice and easy to work with. Everybody agreed that using familiar contexts in tasks and activities is very important and could help us get students more interested and motivated (LE-6; LE-7; I-5). On the other hand, there were cons. For example, links needed to be updated on the Dive into Data section. Also, Unit 2 was less interesting than Unit 1. And finally, the Common Online Data Analysis Platform (CODAP) site was hard to log into and not user-friendly (LE-7). The researcher said that he would forward those concerns to the MOOC team and fix them.

The best thing about the PLT meeting up to that point was sharing. I, and I believe that my friends, too, felt that this was what we needed: sharing our personal practices and discussing statistics (LE-6). Unpacking the MOOC materials together in the meeting was helping all of us to make more sense of the things we learned from the MOOC (LE-7; I-4).

Real and messy data

In Unit 3 of the MOOC, we learned about a statistical task framework for designing, adapting, and analyzing instructional tasks and exploring students' levels of sophistication (LE-1). Again, we also learned about new and cool online tools for data exploration and other helpful resources for teaching (LE-3). Forums included rich discussions about the framework and the new tools. In a forum discussion, Julia stated that she was still trying to wrap her head around the levels of sophistication, but then watching the animations about them helped her get a better

grasp of what was being conveyed. Watching students working with a dynamic survey tool, Julia saw how students would start to progress through different levels of sophistications (LE-4; I-2).

Alan joined Julia's discussion, saying that he agreed with her about finding the animations helpful. He stated that the animations showed how technology aided students' understanding. Then, he shared that he went to StatCrunch and played the game mentioned in one of those animations and found it so helpful for use in his class (LE-3; LE-4; LE-6; I-2; I-5). Reading the discussions about the tasks and animations inspired me to apply the ideas to my teaching (LE-7; I-2). I decided to emphasize that discussion during the following PLT meeting.

For the fourth PLT meeting, I arrived the conference room early, there was a meeting in my department. I had time to buy healthy snacks for the meeting. I was feeling lucky to have a team of enthusiastic participants about teaching statistics. Again, all members were present. K. also virtually joined this meeting. Our agenda today was discussing Unit 3 and included the following: statistical habits of mind, Schoolopoly data drive and investigation, and small group discussions about submitted lessons/task guidelines (LE-1; LE-7). We discussed what to include in the instructor packet while teaching statistics, what a teacher should have in his/her background, and what is the tipping point to be able to teach statistics. We also discussed how to develop statistical habits of mind for our students. Alan felt that it depends on the level of statistics course one teaches (LE-9). Some students, according to him, are more mathematically minded and tend to not like statistics because it is not math-heavy. This was a very interesting point, and I believe that I have thought about this numerous time before. I added that teachers have the same problem that Alan brought up about students (LE-6). There are mathematically minded teachers that really struggle to teach statistics just because they do not have statistical habits of mind. Some questions posed along this line of thought: Why is it important? Why do

math students have a hard time with the uncertainty and what can we do about this? Why do statisticians not discuss the errors and variability? We agreed that these details needed to be discussed further (LE-6; LE-7; I-4).

We also discussed the real-world applications of statistics, such as polling systems. Rosanne mentioned a NPR show discussing this issue. The polling systems do not factor in the U.S. electoral system. The recent U.S. presidential election was a good example for this. The NPR show presented how journalists with internet articles have zero responsibility for being able to recreate the data they use in polling (LE-2).

Another thing we discussed was the Schoolopoly task we saw in the MOOC. Everybody talked about what strategies they used for this activity. We agreed that sample size is important and using a multiple of six for the counts makes the process simpler (LE-7).

We discussed the need for activities to help engage students, especially at the college level. Benna stated that a gender discrimination activity would be useful, instead of a rolling dice activity. She said that rolling dice is an outdated concept and is better suited for basic probability with younger students. On the other hand, a gender discrimination activity would show variability, and it could help with the concept of real decision making (LE-2; LE-6). While doing this, hands-on engagement would help with what happens when you use technology to simulate data (LE-3). Alan suggested an activity called "the black box problem" he uses in his teaching. He suggested giving students an Excel sheet, telling them they do not have to learn all of the formulas, but they are there which makes things kind of a "grey box" situation instead of a black box. Alan's sharing about his personal practice was interesting and several members (including me) showed motivation to try this in their classrooms (LE-6; LE-5).

In this meeting, we planned small group work. We split into three groups according to the following criteria: education group, lower level college statistics group, and upper level college statistics group. Each group included three participants. As a teacher educator, I was in the education group. In my group, we focused on the fact that having students pose their own question could really be helpful for engaging them more in statistics lessons (LE-1). We also discussed that this should be a goal for teaching (I-3). I am not sure about my friends, but this would be a big change for my classes. I used to prepare the questions, knowing that this is the way I should do it. And, I used to struggle to make them good questions, because my understanding of a question and the students' understanding could differ a lot. After that time, my actual preparation was going to be encouraging the student to pose a good question of his/her own (LE-1; LE-7; I-3). Wow!

As a team, we discussed ways to implement statistical tasks. It was very mind-opening to hear others' experiences and approaches (LE-6). I learned a lot by listening to others, especially the ways they overcame or plan to overcome difficulties similar to mine which was very helpful. When a teacher faces a problem and cannot solve it, the easiest way is to ignore it, and sometimes physical conditions force you to ignore it. I think these discussions and the experience of sharing encouraged us to do our job better (LE-6; LE-8; I-4; I-5).

We also talked about a specific task. In that task, students get a faculty data to think about how their lessons are conducted. We also created a canvas site to share the information we discussed in our groups as well as resources we find useful. Finally, we discussed the use of real and messy data (LE-2).

Almost everybody said that they used clean, ready-to-go data in their teaching (LE-6). This point made in the MOOC was a new, eye-opening thing. We talked about the pros and cons

of using clean data or messy data. A pro of using clean data is that the teacher would have predictable results to work with. A con of using clean data is that students do not get to see what messy data or extreme outliers looks like. On the other hand, a pro of using messy data is that students get a real-world example of what data tends to look like before it is cleaned up (LE-7). It is good to expose them to messy data, so they can see how it works in the real world! Also, there are people who clean data and we need to show that in some way. A con of using messy data is that students may try to clean it up and take all the variability out. Learning about real and messy data, and engaging with it in the MOOC, made me question my statistics teaching. I felt a bit guilty because of using only clean data for all those years in my teaching (LE-2; I-3).

Cool resources

I remember engaging in Unit 4 of the MOOC. It was full of new materials to help us understand the different components of a statistical investigation. Census at School was a wonderful source for teaching with statistical investigation phases. Engaging with real data collected from students, thinking like students while doing this, and investigating students' reasoning was so fun and informative (LE-1; LE-2). The discussions about Census at School dominated the forums, and there were great points made by my PLT members. Even though it was a busy school time, the amount of discussion in the forums was impressive. Census at School was going to be a main topic to discuss in our following PLT meeting.

Oh, I remember that things were crazy busy for all of us around that time of the semester. For the fifth meeting, our goal was mainly discussing Unit 4. Again, everybody was present at the meeting. We engaged with Census at School prior to the meeting. I was so excited by the amount of data collected by teachers and students across the U.S. that could be downloaded and used to answer lots of interesting questions (LE-2; LE-3). There is a questionnaire asking

students questions from their foot length to the way they go to school. The online site allows people to filter the data (according to states, age groups, etc.) and get the results. So, this is wonderful to use for engaging with three main objectives in the MOOC: SASI framework, real and messy data, and dynamic technology (LE-1; LE-2; LE-3). The site provides opportunities to have students pose their own question, submit their entries to the big data, collect data for their question, and use this data for analysis in other platforms. This was a great tool, and regardless of all the other cool stuff, the MOOC is worthy to take just for Census at School (I-5)! Two PLT members that are teacher educators were as excited as I am. However, faculty members from mathematics or statistics departments were not that excited. For example, Alan was familiar with Census at School, but he was not a fan of it because he teaches statistics for college students and he is not very interested in education. I cannot blame him; since the data comes from middle and high school students, it is not as relevant to college students (I-6). As a group we decided to suggest to the Census at School organizers that they add questions to make it more relevant to college students. Some concerns about privacy issues were raised; I thought that this was an erroneous concern. Benna stated that Census at School could be very useful in teaching about sampling and variability by taking multiple samples from the database (LE-6).

Teaching students to clean up messy data was another topic we discussed during this meeting. Rosanne claimed that there was a difference between systematic clean-up of messy data (e.g., changing the format of the spreadsheet entries or organization of the data in it), and sporadic cleanup of messy data (e.g., looking for outliers or missing entries). According to her, we needed to teach our students both, especially systematic clean up at upper levels (LE-2; LE-6; LE-7). Vera advocated that it is appropriate for students in intro-level statistics courses to learn about searching for outliers in messy data and how to address them, and it does not have to be

done with large data sets. Benna said that missing data entries is very common in large data sets. According to her, in upper-level statistics classes, we can teach students how to predict what numbers should be entered in a data set to not have empty cells. We further discussed whether it is reasonable to completely remove outliers or not (LE-2; LE-7). We considered ethical issues in doing this as well.

Another topic was useful statistics applets. The MOOC was not only a good learning opportunity about new ideas and approaches to teach statistics, but it was also great in the resources it provided. Alan stated that he uses the statistics applets in <u>Lock 5 website</u> to teach randomization techniques like bootstrap. He prefers it to the <u>Rossman and Chance applets</u> due to a better interface (LE-6). This was interesting for me, and made me wonder about Lock 5 applets, because I had been a fan of Rossman and Chance until now (I-5). Jim added that he uses and likes both Rossmann and Chance and StatKey (the applet in Lock 5). The discussion about statistics applets and applications was very productive and members enjoyed learning about all these opportunities (LE-8). Sharing about personal practices is the best thing about these meetings (LE-6)! We concluded that applets could really be useful in learning statistics, however it may not be as useful for doing statistics. Again, mathematics and statistics instructors like Alan, claimed that we need to teach students how to do statistics in software programs that are used in the field of statistics and data analysis. Rosanne suggested we start using R (a statistical programming language) early and build its use through our courses (I-2). She advocated that insisting on the use of graphing calculators is a big issue limiting the potential better learning of students; according to her, graphing calculators do not support use of data investigations for teaching statistics, which is the focus of this MOOC (LE-7; I-5). Vera added that even though the cons of using calculators are obvious, there is a strength in using them, and it is calculators'

portability and affordable cost. On the other hand, she reminded us that not all students have laptops, or not all schools have enough computers and/or an internet connection to provide this opportunity to the students (LE-9; I-6). Including Vera, we mostly agreed that if the access to computers and internet/software issue is solved, using R or similar programs would help students learn and understand the process the program is performing, and makes the work reproducible which is very important (LE-6). It is important to remember that the context here is college statistics teaching, particularly teaching of introduction to statistics course. After this discussion, Kate decided to try to teach a course with R next semester (LE-3; LE-6; I-5). I cannot wait to hear how it went (LE-8; I-4)! I added another idea to this discussion, thinking that it would be easier for teaching this way. I thought (and said) that it could be useful to have an intro-level statistical computing course to get students started in analyzing big data with R or a similar program that will teach them programming. Alan liked this idea and said that making that course a Gen Ed (General Education) course would help its enrollment (LE-6; LE-8; I-3; I-5). This could possibly get buy-in from other departments whose students need to know how to analyze data as well. The current programming course required for math majors teaches Java or Python which is not meeting our needs.

We received lots of valuable resources and ideas from this course, I am pretty sure that my friends felt willing to try these ideas, approaches, and tools in our teaching (I-5)!

Baby steps

I was excited to finally be in Unit 5 of the MOOC, focusing on changing teaching practices to engage students in doing statistics with real data. Mainly, we were expected to reflect on what we learned throughout the MOOC. Julia initiated a nice forum discussion telling how she enjoyed taking the MOOC, and how it gave her so many ideas to try in her teaching

(LE-8; I-5). Benna joined this discussion saying that she agreed with Julia, and she thought that these are baby steps for statistics education. Benna stated that a longstanding misconception has just ended, and statistics education just started to have right recommendations. According to her, there should be much more effort to improve statistics education (LE-1; LE-2; LE-3; I-4). I took a note with uppercase letters to initiate a discussion during our final PLT meeting about potential changes in our teaching practices.

The final PLT meeting was here. Because of heavy coursework, two participants were not available to join us that time. Rosanne, Benna, Vera, Jim, Alan, K., and I were present.

As it was the final meeting, I planned to discuss the big ideas we learned from the MOOC. The leading questions for this discussion were about the salient aspects of what the members have learned in the MOOC; how the course helped them to create a vision of how to move their practice forward; and what the members were interested and willing to learn more about teaching statistics. Each PLC member was asked to respond to these 'big ideas' prompts. I remember reading through members' responses and noting those responses (LE-6; LE-7).

Vera stated that she learned more ideas about data collection that will be interesting to her students, and about how to clean data (LE-2). She also admitted that it was the first time for her to think about the differences between mathematics and statistics (LE-1).

Benna stated that while statistics was not a course on her "want-to-teach" wish list, she is not dreading it any longer, and she is ready if called on to teach statistics (I-1). She loved the idea that the resources from the MOOC will be available online after the course ends (LE-8; I-4).

Jim stated that he will now pose questions more forcefully to students and get students regularly involved in collecting data (LE-1; I-3). Also, listening to the expert panel discussions,

especially hearing a panelist say that he used to teach his statistics classes mostly through data visualizations, he decided to emphasize data visualizations more (LE-5; I-2).

Alan pointed how he became motivated to try new ideas and approaches, such as incorporating more data work in class (LE-1; LE-2; I-5). He also said that he is willing to completely change his class to be data-driven (LE-1; I-3).

Rosanne was more than happy to join this PLT as a new teacher. She thinks that she gained more than she can even imagine. According to her, the best thing was encouraging each other to progress to learn about statistics and improve teaching skills (LE-8). She was determined to find other ways to contribute to her learning about new ideas and approaches for teaching statistics, such as reading research articles and attending other PDs or online courses (LE-8; I-4).

Both our engagements in the MOOC and in the PLT meetings motivated us to continue learning about statistics teaching and encouraged us to develop a commitment to improve our teaching statistics skills (LE-1; LE-2; LE-3; LE-4; LE-5; LE-6; I- 4). We discussed how to do this, and some ideas were interesting to note. I promised to take the lead on making an instructor packet for a course, including highlighted resources from the MOOC. I planned to include the following in this packet: make teaching more coordinated; make decisions about software use; use real data; continue to share good data sets (I-4).

Alan promised to compile data about what topics different teachers address in a course so that we can discuss it next semester. We decided that we need to continue to discuss what software to use in which courses and we discussed the use of R, Excel, and Python (LE-2; LE-6; I-4; I-5).

Other discussion points were on the table at this meeting. For example: how should we address the varied knowledge students have of statistics coming in? I think that this was an issue about education in all subjects.

Another issue was assessment. What is the best way to assess our students in statistics? At this last meeting, we agreed that there must be a balance of exams and projects (LE-9).

We also questioned the Common Core standards (LE-9). TSDI components do not exist in the standards. How would a statistics teacher know about the SASI framework, real and messy data, unless taking this course or having read it in an article (LE-1; LE-2)? It looks like Alan was right when he said: "These all look like baby steps in the field; there should be greater efforts to make better steps" (LE-8; I-4).

Ending

The interview for the project is in an hour. I think I will share my meeting notes with the researcher. My confidence to teach statistics has increased, and I am 100% confident in saying this (I-1)! Also, my interest in and curiosity about teaching statistics has increased after leading and participating in the PLT (I-4). It was a fulfilling experience. Unfortunately, I did not have a statistics course to teach during the following spring semester, however I am determined to make big changes to my teaching next year (I-1; I-3; I-5).

<p style="text-align:center">PLT Member Vignette</p>

The following description, through a narrative vignette, is an account of Albert's experiences as a PLT member. The vignette is based on the data collected from PLT meeting notes, MOOC course surveys, PLT follow up survey, MOOC forum discussions, and PLT member interview. Additional characters (other members in Albert's PLT) will be woven into the story for illustrating specific experiences that may be relevant to research purposes. During

the narrative, lived experiences and impacts described in the previous section will be used to reflect the findings of the study.

Albert's story

Albert is a high school mathematics teacher and has been teaching statistics for several years. He did not have any online course experience before. He had experiences in various professional learning communities in his school, mainly to improve mathematics teaching in their school. Albert joined the MOOC and PLT for learning about new ideas and methods to teach statistics. In the beginning, he stated that he assumed joining a PLT was a requirement for taking the MOOC, which was a misunderstanding; however, he also stated this was a great misunderstanding.

Albert joined a virtual PLT of high school mathematics teachers from various states on the east cost of the U.S. This PLT was led by Lora, who has a deep interest in teaching statistics and previously conducted several workshops about teaching statistics. The subject of the vignette will be Albert's experience as a PLT member and a MOOC participant.

Setting the stage

To set the stage, a PLT member, Albert, is preparing for the post-PLT interview, and he is thinking about how he started this experience, joined a team, participated in the meetings, and engaged in the MOOC. The following vignette is an account of Albert's experiences, feelings, and perceptions leading to this day.

Waiting for the interview

It is a sunny and relaxing weekend after a busy school year, and it feels good to know that tomorrow (Monday) is not a school day. I decided to document my experiences in the MOOC and PLT, because I do not want to forget anything. Since I started teaching statistics,

including taking a college course about statistics, I never learned that much about the thing I am teaching. Not only have I learned new things through this MOOC experience, but I also faced the fact that I was doing things incorrectly. I need to have a record of my experiences. Who knows, I may have the courage to make real changes in my teaching next fall.

I remember when Lora emailed me about this project called "Networked MOOC-Ed." I know her from a workshop we both attended last year. She is an enthusiastic mathematics teacher and very interested in statistics teaching. She has several articles published and participated in some research studies about statistics education before. When she asked me for joining her PLT, I misinterpreted it and thought that this was a MOOC requirement. I accepted her invitation. I could say that this was one of my best misinterpretations. If I was not a part of the PLT, I would not have engaged in the MOOC after a while, because I am lazy, and I have too much workload at school. Also, if was not in a PLT, I would miss all the discussions about the MOOC materials and personal practices (LE-6; LE-7). Also, statistics was my weakest side in teaching; I used to feel insecure about teaching it. For all those years, I was a little depressed when I had to teach statistics. This whole experience really increased my confidence to teach statistics (I-1).

Initial engagements

Our initial PLT meeting was held virtually and seven members joined this meeting, including me. It was an orientation meeting before we really started to engage in the MOOC. All members were high school mathematics teachers, but we were in four different states!

After introducing ourselves briefly, Lora gave us a short presentation about the project. She said that we will have several meetings to discuss our MOOC engagements and teaching practices in statistics. We agreed on a meeting schedule. All meetings would be held virtually,

and Lora promised to record every meeting and share those recordings with us. For that first meeting, the plan was to discuss common ideas and issues about teaching statistics.

Critical thinking and making decisions based on data was one of the topics we discussed. We all agreed upon the idea that those are very important for students' learning of statistics, however, college expectations for high school students were perceived as a barrier for learning statistics appropriately (LE-6). Another issue was that the content of statistics has been changing frequently, and students should be informed about these changes, and this creates a challenge for teacher (LE-9). Teachers get confused with the changes in statistics. We all know that most mathematics teachers do not like teaching statistics, and I do not like teaching statistics, because it is not exactly mathematics. When teachers do not prefer teaching statistics, how could the quality of the statistics education be good? Even in high college, no real statistics is learned or taught, according to some research. One team member gave an example from the community college she taught in before. She said that it was a big college with 19 mathematics instructors; when a statistics teacher was needed for a course, only one teacher volunteered to teach it (LE-6).

Another issue we discussed, and I have no idea how we fell into this detail during the meeting, was the reason for taking p-value 0.05. To be honest, I never thought about this before. I am not a very curious person. But, this was really an interesting discussion, and made me wonder about statistical content. I should check and work to improve my statistical knowledge (LE-6; I-4). We made an online search to answering the question about p-value. After getting a an answer from a Google search, the issue was transformed to how to explain this to students (LE-9). We could not reach an agreement about the right approach to this problem.

Then, we discussed about the context used in statistics lessons. Lora advocated that talking with a heavy technical language about an unfamiliar subject like medical research would be a terrible choice for teaching statistics in high school (LE-1; LE-7). A teacher could use an easier subject, such as students' soda consumption, sports teams' score numbers, or student presidential elections. Not only are these subjects easier, but they also are interesting for students (LE-6). One member, Hannah, recommended we watch a YouTube video called "Power of a Test" because she thought that it was a good source to address our discussion points in this meeting (LE-4).

More attention for statistics

The first engagements in the MOOC were surprising for me, because I never saw statistics from this aspect. Instead of mathematics in statistics, the course provided an opportunity to learn about exploring with data. The main theme was how to engage students with real data and cool tools to use in teaching statistics (LE-2). Statistical reasoning was not something I paid attention to before (LE-1). Forum discussions were very interesting and inspiring. I remember that a participant asked a question about the explanation of p-value. The discussion was a long one, and I tried to present my ideas, as well. That participant asked for an explanation of the concept in simple terms. Several confusing answers were given, and those showed how the concept was misunderstood or not known by teachers. I answered the question, saying that p-value shows how statistically significant the data is. Another way to think about the p-value is that it shows how likely it is that the results would happen by chance alone. Then the discussion went on to focus on the reasons for choosing certain values as p-values. I am not sure whether the first participant asked the question was satisfied with the responses, but I am pretty sure that the discussion made many teachers wonder about it (LE-6; I-4).

In our second PLT meeting, our PLT leader, Lora, asked us whether we completed Unit 1. Everybody confirmed that they completed it. Next, the leader asked us what important points we found in Unit 1. The "Statistics for All" article in Unit 1 was a great source and was so inspiring to make changes in teaching statistics (LE-1; LE-7). Then we discussed the "Jane's age" task (see appendix). I found this task to be a very surprising example. According to Hannah, the task was great in some respects, and difficult in some others both to understand and to teach with. According to her, the difficulty of the task came from the different nature of the problem (LE-7). It was not a common problem type. She said that this could be because of the task's broader aspect, and that teachers are used to use more minimal and limited data questions, such as dice rolling experiments (LE-6). In the Jane's age task, there is no limit for the variation of data that could be collected; it is far different from having numbers from one to six. Gilda added to this discussion, saying that the task shows that statistics is more open to getting students involved than any other mathematics subject. In this task, students are involved in every step, from asking a question to lead students to find Jane's age, to collecting appropriate data and analyzing it with online tools (LE-1; LE-2; LE-3). I contributed to the discussion by saying that a student could ask whether there was any mathematics in this question. From our readings in Unit 1, we now know and see why this is a case in statistical subjects; this is because statistics is not a subject of mathematics but is a separate discipline. However, how would we teach this to the students who encounter statistics only in mathematics lessons for now (LE-1)? Shouldn't it be a separate class? Some team members agreed that the answer to this question is yes; others thought that there is not enough content in statistics to fulfill a whole semester class for beginners.

The online tool Gapminder was another topic we discussed at this meeting (LE-3). The members agreed that this was an excellent tool to use with students; it is easy to use and provides

a virtual and dynamic experience with data (LE-7). I was glad to learn about Gapminder. When I saw it in the MOOC, I did not pay that much attention to it. It may be my laziness again. The PLT meeting helped me discover it and see the opportunities it provides for teaching statistics (LE-3; I-2). Lora pointed out that having lots of resources is a great thing, however, we have a limited chance to use them because of time constraints (LE-9; I-6).

Lora asked us the following question: "What is being done to enhance statistics?" The only thing I could answer was that statistics was added to the SAT exam last year. Other than that, I did not remember anything. Ada mentioned state funded professional development about statistics education; according to her those efforts have been increased recently. She also added that there is still an issue about statistical content; for example, students jump into hypothesis testing after only learning basic probability. These kinds of content-related issues were discussed for a while. In Pennsylvania, she said, students pass Algebra only to pass the state test, thus they ignore studying or learning statistics. Finally, we all agreed that statistics' place in curriculum needs more attention (LE-6; LE-8; I-3).

Encouragement for progress

In the second unit of the MOOC, we learned about the statistical investigation cycle and statistical habits of mind. To be honest, I did not know anything about these before. I knew what each phase represents and what each habit of mind means, but I did not know this idea of teaching with consideration of the investigation cycle and attending to the habits of mind. In this unit, the MOOC provided nice statistical tasks and cool web-based tools to use in statistics lessons. I also watched the videos where the teachers and students engage with those tools. The forum discussions were mostly about those tools and tasks. One discussion was about one of those online tools, CODAP. I always disliked the idea of using paid tools in the classroom.

CODAP is a web-based, open source alternative to Fathom. In fact, CODAP is not completed and it is not quite an alternative yet, but at least it promises to be so. In that discussion, I shared my ideas about this tool and how it is nice to hear that a free tool will be available to use for statistics lessons (LE-3; LE-8; I-2).

I questioned my teaching during this unit. This was not normal. I have been teaching for years, and I always feel that I am a such a good teacher that I do not need to add anything. My lack of confidence in teaching statistics led me to take the MOOC, and a misunderstanding threw me to into a PLT. For our third PLT meeting, there were five participants in total; two members were not able to connect. In that meeting, we discussed Unit 3. Lora started the discussion talking about levels of sophistication (LE-1; LE-7). Everybody in the team, including Lora, was surprised to learn about these. I said, "who knows what else we do not know, and we should know about teaching statistics" (I-4).

Ada brought up the issues in the teaching of conditional probability. Her students asked Ada whether there was a way to calculate winning lottery numbers. Her quick "no" response made Ada wonder about this. She realized that her knowledge about conditional probability is formal and cannot relate to the real world. Then, she repeated her student's next question: what is the point of learning probability (LE-6)? It is a commonly known issue for mathematics teachers. There have been questions about how to use the things they learn in real life among students for centuries (LE-9). However, different from mathematics, real world examples are very important for statistics, because statistics includes a huge role for context (LE-2). These are the thoughts I noted from our discussions. We also talked about p-values again. I think teachers bring up this problem because even they search for answers about it; it is not an easy thing to understand. In

the end, one could just say that "you know what, it is just chosen as .05 or .01; there is no mathematical background for this" (LE-6; LE-9).

The best part of this meeting was hearing a member say that she feels encouraged to learn with the help of the PLT (LE-6; LE-8; I-4). I also feel that, as I said during the meeting, it is still very difficult to encourage another teacher to get curious about new ideas and approaches about teaching statistics (LE-9; I-6). Not only for teaching statistics, but for all subjects. Our teachers are conservative, they do not want to progress, or they just do not take a step toward it.

Discovery and sharing

The third unit of the MOOC was about levels of sophistication and how to apply the new strategies to statistical tasks. I hate categorizing students, so I was skeptical about this idea of levels of sophistication. However, when I saw the details of why it is necessary to know the levels A, B, and C, and structure the tasks or problems according to these levels, I was convinced to learn more about it. The Schoolopoly task was very cool; I am pretty sure that I will use it when I teach probability next year (I-2). In a forum discussion about Schoolopoly, one member stated that he or she found a bug in the simulation. I need to look at and understand what that bug was about. I hope that it was not a big deal. I think simulations always have bugs. I wrote about this in the forums. How could we make sure that a digital simulation has a safe mechanism for randomness? There is always a system, either a seed value for calculators, or an algorithm in software. How could I answer a student's question and convince him or her that the simulation can represent a random event? I did not get a convincing answer, and I think it is difficult to get one (LE-9).

The fourth PLT meeting was a week after the third meeting. The time between our last meeting and our upcoming meeting was a bit short compared to others. This was because of

schedule conflicts among the members. Even though there was a short time between the two meetings, I had a chance to explore some of the resources in Unit 4. Lora suggested we take a look at some of the resources together through screen sharing. She also posed some leading questions for discussions about Unit 4. The first question was: "A big focus in this unit was learning to use messy data that has many variables. Why should we engage students in using such data? What challenges may occur when using large data sets" (LE-2; LE-7)?

I answered this question, saying that students like the idea that they deal with real data. From my experience in all those years in teaching, I believe that making students feel they do useful things impresses them (LE-6). Lora agreed, saying that it is important for students to have this change, but cleaning data would take lots of time, which could create an issue for teaching. She added that it is difficult for students to judge the reliability of data (two hours sleep could be valid and not ideal at the same time). Ada answered this question by reminding us that the idea of dealing with uncertainty makes teaching statistics more difficult for teachers; and in dealing with messy data, the justification of including or excluding outliers is a difficult problem. According to her, outliers are disturbing for students, because they do not like to hear about what they should not do (LE-6). Sarah stated that she never purposefully used messy data, but when she does, students get their own experience dealing with messy data and this was a fantastic thing to observe. Sarah's experience reminded other members about their experiences, and we realized that students' creativity is also a factor in changing instruction (LE-6; I-2).

The second discussion question was: "In what ways have you used the Census at School website, either contributing to the data or using the data?" Sarah answered the question first: "We do not have textbooks this year (yeah!); I have a supplement textbook. Unit 4 was my favorite unit because of Census at School" (LE-7). Just like Sarah, Ada and Gilda were glad to

know about this online database and tool. I also liked that source. Unfortunately, I finished the curriculum before I started this unit; however, it will definitely be a part of my teaching next year. The idea of having an actual website from other schools and access to this giant database is a wonderful thing! I am planning to collect this data from all students in my school. As the head of the mathematics department, I believe this will not be very difficult (LE-6). After the point made about Census at School, Lora made a demonstration she prepared using Fathom to analyze the data collected from Census at School, along with a discussion about different aspects of the tool and Fathom. She also reminded us about CODAP and tried to do parallel work with CODAP (LE-3; LE-7; I-2).

The third discussion question Lora asked was: "During one of the expert panel videos, Wester West said (paraphrase) 'Statistics is not something you can do on a hand-held calculator.' What is your reaction to that statement? Agree? Disagree? Somewhere in between" (LE-5)? After asking the question, Lora added her thoughts, saying that there was so much more in statistics than just calculations. Gilda stated that student's job in a statistical task is to analyze what data it has in it, and technology could definitely be used to ease this work, but it is not what a calculator does. In my opinion, this is right, especially if our purpose is to teach statistics through data investigations in which case calculators are almost useless (LE-1; LE-3). On the other hand, until I took this MOOC, I had no idea about this very important thing about statistics. Statistics is heavily about data and cannot be understood only with calculations (LE-1; I-3). Learning about the SASI framework, real and messy data, dynamic technology, sharing about personal practices, unpacking MOOC materials, and being encouraged to continue learning *(*LE-1; LE-2; LE-3; LE-6; LE-8; I-4) were revolutionary experiences, and I am sure that they will

impact my teaching in statistics. I cannot wait to start trying these ideas, approaches, and tools in my classes (I-5).

During this meeting, we also talked about the ideas we found in the online forums to discuss. Even though almost everybody engages in the forums, we may skip some important discussions or ideas in there (LE-7). Every member gave some examples of when they discovered a new thing or liked an idea to share from forum discussions. For example, I talked about the discussion with the glacier/climate change example. Some MOOC participants talked about potential consequences of using that kind of data. This is not only real, but also very important for students to think about (LE-2; LE-7). Also, another MOOC participant asked whether it is okay to delete outliers, if there are any, in those kinds of scientific data. I thought that it was an important discussion, and most of my PLT friends had not seen that discussion in the MOOC. We discussed this issue in several different contexts, such as medical or economic data examples. Even though there was not a complete agreement, the discussion was great in terms of strengthening our perspectives about the issue (I-5).

Plans for change

In Unit 4, we learned about materials to assist us in understanding the components of statistical investigation. Those materials were available to directly use with students. The coolest one was the Census at School project. I was surprised to see that there was such thing, where student responses to a survey are collected and open for use in teaching purposes. In forum discussions, several teachers talked about how they used Census at School in their class, and how it went. Some participants stated that their experiences were negative. I think including a full lesson plan with Census at School in the MOOC would be very helpful to show its potential. I decided to work on it and prepare one for next semester (LE-7; LE-8; I-4).

Unit 5 of the MOOC was mainly about ways to change teaching practices that could engage students in doing statistics with real data. We were expected to reflect on our experiences and learning throughout the MOOC. Forum discussions provided great plans that I asked for permission to use in my teaching.

Our final PLT meeting was less about our engagement in Unit 5, and more about how each member of the team found the overall MOOC and PLT experiences (LE-6). We started discussing the recent AP statistics exam questions. The discussion about Unit 5 did not last long, and we moved forward to talk about our overall experiences in these two communities (MOOC and PLT). Lora wanted us to post a statistical lesson or activity and record a short video describing the lesson and activity (LE-8). After those are shared, we all will watch those videos (LE-4) and critique the activities and offer suggestions for improving them. As of this time, I have not uploaded mine, and did not see others' videos yet (the last meeting was last week, and we have a month to do this task) (LE-6).

Our team members' feeling about these experiences were so positive. Hannah and Gilda said that they already changed the way they teach statistics (I-5). They both were teaching the course this semester, and bravely applied the SASI framework and real and messy data to their lessons (LE-1; LE-2; I-2; I-5). I think that it is a brave action, because it is not easy to change your practice this fast. I was done with my curriculum in statistics, however, I would not easily make those changes. Even though I also loved all that I learned through my MOOC engagements and PLT meetings, I have to study those throughout the summer and then make changes (LE-9). I always hesitate when it comes to changing stuff in the classroom. I do not want to affect my students. Hannah and Gilda were so happy with the consequences though. Hannah said that students' interest has been increased this semester. Gilda has been using various online tools and

tasks from the MOOC, and she added to what Hannah said, saying that she as a teacher feels more excited about the class, as well (I-5). That is great to hear! I am more motivated to review everything I learned and try new things next semester (I-4; I-5).

Ada and Mina were absent in this meeting. Sarah was feeling overwhelmed with the end of semester and she did not teach statistics this semester (LE-6). She also told us that she is planning to make changes in her teaching next year, if she teaches statistics (it was not certain yet) (I-4; I-5).

Lora was so happy to lead this team, and she was trying to offer ways to keep in touch and maybe continue to meet as a PLT next year, to discuss our practices, and the changes in our practices (LE-6; LE-8; I-4). That sounded like a nice idea! Lora was very organized and thoughtful in leading this PLT. She sent out the discussion questions in advance for every meeting. I was a procrastinator sometimes, I admit. As a department head, I have lots of burden. But Lora's emails and PLT meetings encouraged me to work more on the MOOC and pushed me to do all MOOC requirements (LE-8). At the end of the meeting, I was grateful to be a part of this!

Ending

I am not a young man. I am not a new mathematics teacher, either. However, after this semester, I felt just like a preservice teacher. I was not a statistics teacher before; I could easily admit that. I was teaching mathematics. My approach in teaching some specific subjects has changed. I can say that. I will try to use more real and messy data (LE-2; I-5); this is for sure! The one thing that really struck me was the use of real and messy data. The kids used to get the data very unrealistically clean and just ready (LE-6). My way of teaching will change in this sense, because now I know that the other way (teaching with ready-to-go, cleaned data) is just

wrong! I feel a little guilty for not taking the MOOC last semester, when I attempted to the first time. That way, my students in spring would receive more appropriate information and more sophisticated experiences with statistics (I-5). Anyway, I hope that I will use this next fall. Encouraging students to get their own questions, letting them think about and do the data collection, use online tools, offer better and more appropriate statistical tasks, make them think about real world applications of statistics (LE-1; LE-2; I-5) will be wonderful! All the notes I documented about my PLT friends' approaches and experiences will be a part of my self-study during the summer. They always say that sharing with others about professional practices is good for improving teaching. This was the first time I deeply agreed with that, and luckily this happened after a misunderstanding. I wish there was kind of a follow up for the MOOC next year (I-4). They were talking about another MOOC focusing on "teaching statistics through inferential reasoning." If it is available, I will take that (LE-8; I-4).

CHAPTER 6: DISCUSSION

Introduction and Evolution of the Study

The purpose of this study was to identify the effectiveness of a blended professional development effort for the professional growth of teachers in their teaching statistics practices. Identifying the effectiveness of professional development in participants' professional growth is not easy work. As the research was phenomenological, the lived experiences within the phenomenon should be described. Participants' lived experiences within the phenomenon of participating both in a MOOC and PLT were complex. By coding to describe any lived experience, then collapsing similar ones and ignoring occasional lived experiences, there were nine final lived experiences described in Chapter 4 that captured the majority of the experiences across PLT members. By participating in the blended professional development experience, PLT members were:

- Learning about and applying the SASI framework (LE-1);

- Learning about and engaging with real and messy data (LE-2);

- Learning about and engaging with technology (LE-3);

- Observing practices from videos (LE-4);

- Listening and reflecting upon expert panel discussions (LE-5);

- Sharing about personal practices (LE-6);

- Unpacking MOOC materials (LE-7);

- Encouraging each other to progress (LE-8);

- Being concerned about content or practice (LE-9)

Of importance in this research is how the lived experiences may have changed or influenced participants' perspectives about and/or practices in teaching statistics. Coding all

sources of data led to six dominant impacts that were identified and explained in Chapter 4.

Those impacts were:

- Gaining confidence in teaching statistics (I-1);

- Increasing instructional repertoire for teaching statistics (I-2);

- Changing goals for teaching statistics (I-3);

- Developing a commitment to continue learning skills to teach statistics (I-4);

- Willingness to try new ideas and approaches in teaching statistics (I-5);

- Limiting potential professional growth (I-6)

This chapter will attempt to succinctly answer every research question and discuss these findings' connections to research literature and implications for the relevant field. Also, the limitations and implications of the study will be discussed. The chapter will conclude with a section describing recommendations for future research.

Summary of Research Questions and Findings

There are several findings to present, and those will be presented with their relation to the research questions that guided this study.

1. How does participating in a MOOC and a PLT focused on teaching statistics impact teachers' professional growth in:

    a. Perspectives and beliefs about teaching statistics?

    b. Confidence in teaching statistics?

    c. Understanding how to support students' approaches to statistical investigations?

2. How does participation in a MOOC and PLT impact the nature of planned or self-reported use of various instructional strategies for supporting students' approaches to statistical investigations?

Research question 1

PLT participants had impressive completion and activity rates in TSDI MOOC. PLT participation encouraged the participants to richly engage in the MOOC and complete it. By completing the MOOC, participants engaged in forum discussions, read the articles, listened to the expert panel discussions, watched the classroom videos, and completed purposefully designed (designed to understand the impact of their participation) surveys. Data logs showed that PLT members and leaders were very active in the course, had sustained engagement, were active discussion forum participants, and accessed many course resources. In their PLT meetings, they met with their colleagues five or six times throughout the MOOC to discuss their learning and engagement in the MOOC, and to share their teaching statistics experiences. This provided evidence about how they learned from the course, and how this learning impacted their perspectives and beliefs about teaching statistics. Participants' forum entries reflected their learning of MOOC elements, such as the SASI framework, the use of real and messy data, and engaging with dynamic technology. They both praised and questioned those elements, especially toward the end of the forum discussions; the language they used in those forums significantly changed from talking more about the curriculum issues and students' situations to including those elements in planning different strategies they wanted to implement in their practice. To give a specific example, the TSDI MOOC is designed to increase teachers' understanding of students' approaches to statistical investigations (SASI) and help them learn to teach through data investigations (Lee & Tran, 2015a; 2015b). Most of the PLT participants stated that being a

part of a PLT, they had a chance to share about personal practices (LE-6), and to unpack the

MOOC materials (LE-7). Those lived experiences helped them to understand MOOC contents

better, and thus their understanding of the SASI framework. Participating in a PLT positively

impacted MOOC participation and motivated the participants to try new ideas and approaches in

teaching statistics (I-5).

In response to question 1b, as explained in the previous section with supporting evidence,

PLT participants' confidence in teaching statistics increased. Attending the TSDI MOOC and

PLT, the participants reflected that their self-confidence to teach statistics increased. This claim

is supported by both SETS quantitative results and open-ended responses in SETS. Also, in other

survey responses and forum entries, participants reflected on how their confidence increased

with the help of lived experiences such as encouraging each other to progress. This finding is so

important, because as shown in Chapter 2, there is a common and strong issue with teachers'

confidence to teach statistics (Stohl, 2005; Estrada et al., 2011; Lovett, 2016). Teachers mostly

escape from teaching statistics for various reasons. One of those reasons was the lack of their

knowledge about different strategies in teaching statistics (Hill et al., 2005). Learning about and

applying SASI framework (LE-1), learning about and engaging with real and messy data (LE-2),

learning about and engaging with technology (LE-3), sharing about personal practices (LE-6),

and encouraging each other to progress (LE-8) constructed a rich knowledge and experience for

the participants, which helped their confidence increase (I-1).

As explained earlier in the framework section, to examine participants' professional

growth (Clarke & Hollingsworth, 1994; 2002), enactment and reflection processes between

external domain and personal domain, and between external domain and domain of practice are

examined for these findings. As a result of their participation in the MOOC and PLT, the results

chapter showed that (both sections of the chapter) participants' professional growth has been improved in all three categories:

- their beliefs and perspectives are impacted (I-3; I-4; I-5);

- their confidence is increased (I-1);

- their understanding of how to support students' approaches to statistical investigations is improved (I-2; I-3).

Research question 2

How does participation in a MOOC and PLT impact the nature of planned or self-reported use of various instructional strategies for supporting students approaches to statistical investigations?

Teachers are concerned about content and practice in teaching statistics (Godino et al., 2011). This was found throughout both semesters' forum discussion entries and in the meeting discussions of PLT participants, as well as in PLT interviews. Almost all topics were discussed in both platforms and addressed those concerns. Teachers are concerned about their students' learning, and they want to make sure that a change will not hurt them at all (Lovett & Lee, 2017). The participants who were active statistics teachers especially expressed concerns about the content they teach and about their practices. Being concerned about content or practice could form a barrier to the desired impact of this research. Even though what was learned from the MOOC and PLT was appreciated, applying those new things to practice could not take place if these concerns are not addressed well. On the other hand, sharing about practice, observing videos of statistics practices, and unpacking MOOC materials were life-saving lived experiences for teachers to not give up on changing.

There are several external factors influencing participants' professional growth and those need to be addressed in future studies. Other than teachers' own concerns, there are several factors influencing the desired impact of the TSDI MOOC. Time constraints, district or school rules, curriculum requirements, lack of access to technology tools or other resources, and students' priorities for exams affect teachers' openness to change.

Participants needed more examples about how to apply the changes to their practice. Several participants stated that, even though they liked new ideas and approaches in teaching statistics, they felt the MOOC did not provide enough examples for them to have a clear idea of how to apply those changes in their classroom. According to those participants, change is naturally difficult when it comes to teaching, which is already a more complex action; and when it includes teacher and learner, it becomes more difficult. To make the change possible, there should be sufficient examples of how to apply new strategies (Avineri et al., 2016).

With the lived experiences in the external domain, participants reflected a strong willingness to try new ideas and approaches in teaching statistics. This willingness was obvious in that they were excited to hear from colleagues who already tried those ideas and approaches (I-5).

Developing a commitment to learn and new skills to teach (I-4) is found to be essential for positive changes (Clements et al., 2011). Participants developed a commitment to continue learning about teaching statistics. They liked to see the way statistics education grows, and they wanted to keep learning about the field. They were curious about what potential statistics education has, and they were also curious about how it could evolve.

There seems to be a lack of examples in teaching statistics, not only in what we provided in the MOOC and PLT, but also in general (Batanero et al., 2011). Active teachers especially

pointed out that most of the cool stuff they learn about statistics teaching does not draw a clear image in their mind about how to fit it into a lesson. This may be because of the unique nature of statistics education and the fact that it is not as old as other disciplines (Ben-Zvi & Garfield, 2004). As highlighted several times in Chapter 2, being integrated into mathematics may limit the potential statistics teaching carries and separating statistics from mathematics as a lesson should really be taken into consideration (Garfield & Ben-Zvi, 2008; Callingham & Watson, 2011; Pfannkuch, 2011; Lee & Strangl, 2015).

Limitations of the Study

We found that blended professional development was impactful in educators' teaching statistics perspectives and planned (self-reported) teaching practices. It was especially impactful in participants' engagements in the MOOC. But there were some things which did not go as planned. For example, the question "How do I teach this?" remained unanswered for several participants, because, according to those participants, there were not enough exact lesson plans or task examples offered in the MOOC. Those examples could be added in future MOOCs to solve this potential issue that could be related to other MOOCs as professional development.

Reflecting on the study led to several critiques that could limit the desired effectiveness of the study results. These critiques are connected to various limitations of both participants and research design. Even though these critiques could not change the current study, for future studies, they could guide researchers to avoid similar limitations.

Participants' limitations

Most of the participants were high school, community college, or university instructors that are teaching or planning to teach statistics. Those participants are bound to their curriculum requirements, school or college sources and expectations, and time.

Two PLTs during spring semester were not as active as others in providing data; this was an unexpected situation. For those two teams (including five members in total), we had only partial MOOC data.

Spring participants were especially hesitant to participate in interviews. They all were high school teachers. When they took the eight-item statistics assessment in Unit 1 of the MOOC, their poor results negatively influenced their openness to reflect upon their experiences for research. Four teams did not allow me to join their meetings as a non-participant observer. Only one member from those three teams participated in PLT interviews. Thus, the interview data and notes from PLT meetings really only captured the lived experiences of the PLT aspect of six teams.

Research design limitations

Phenomenology was chosen as the research design of this dissertation study. This methodology was a good fit because we were mainly interested in understanding the nature of the phenomenon of participating in TSDI MOOC and PLTs. However, none of the methodologies are perfect, including phenomenology.

According to Daradomuis, Bassi, Xhafa, and Caballe (2013), MOOC design needs to favor a learner-centered approach that provides "strategies that change the perception of learners as active participants in the establishment of individual goals and a personal trajectory" (p. 208). Thus, MOOCs should allow content customization based on user profiling which optimizes the process of learning. According to the authors, managing a MOOC for large amounts of participants requires adapting a tutor-assisted e-learning model as well as the use of automated tools, which could "complement the lack of human attention while maintaining acceptable quality standards" (p. 209). Nevertheless, the TSDI MOOC did not include an intelligent system

to assess or measure the participants' engagements. This could be considered another limitation. In a potential future study, either the MOOC could be enriched with an intelligent system, or a totally different professional development could be used as a part of this blended professional development.

Coffrin, Corrin, de Barba, and Kennedy (2014) stated that having performance data in a MOOC, such as the analysis of the state transition diagrams, could contribute to our knowledge of the patterns of participants' behaviors in MOOCs, which could contribute to success. Even though the article discusses MOOCs for students, the finding could be related to MOOCs for teachers. Our data sources were mostly self-reported reflections of participants about their experiences. There was no performance data related to understanding the content of the MOOC or of teaching practices, which could be considered as a limitation.

For examining the changes in participants' teaching practices, participants were asked to upload pre- and post-statistical tasks for classroom use. Unfortunately, the data was insufficient to analyze, thus I decided to exclude those tasks from data analysis. This created a concern because there was no other way to directly examine the impact of the study in participants' teaching statistics practices. Another way to examine the practices would be conducting observations of their teaching. However, time and resources were limited since there were no teams local to the researcher.

At the beginning, the plan was to select 10 PLT leaders from former TSDI MOOC participants and let them form 10 local PLTs during fall 2016. This plan did not work as expected for two reasons. First, the selection was limited with volunteer leaders who could find members to take both a MOOC and join a PLT. Even though there were 12 potential leaders at the beginning, only four of them were able to form a team. Those who could not form a team

either were not able to convince enough people to take the MOOC, or they could not arrange their own time to do this. For spring, the selection process was different. From MOOC enrollees, we reached out to people who seemed to have an interest in and curiosity about improving statistics teaching. If we had applied this criteria to the fall selection process, we would not be limited that much, and possibly would have had all teams formed for fall 2016.

There was a potential research bias that needed attention. My dissertation chair was the principal investigator (PI) of the PLT project. Also, I worked as a research assistant to form the PLTs and assist the leaders throughout the meetings. This could be a possibility for researcher bias. However, one of the impacts we found was negative (Limiting professional growth [I-6]), and the existence of this negative impact made us comfortable in saying that the potential for researcher bias was already overcome.

Implications

The implications of this research include encouraging teachers of statistics to attend blended professional development projects like the external domain of this study. Learning about new ideas and approaches to teaching statistics requires both learning about those ideas and approaches and sharing about practices with other colleagues.

Through examining 63 PLT participants' who participated in the TSDI MOOC and in the PLTs the following, recommendations could be made for teachers of statistics to grow professionally.

MOOCs are a great way to reach a large number of teachers who want to learn about and engage with new strategies and sources in statistics education. Just as it appeared in the TSDI MOOC, researchers in the field of statistics education have designed and offered other MOOCs about teaching statistics (Lee & Stangl, 2015), and those efforts could impressively impact the

field of statistics education (Donald et al., 2017; Wild et al., 2017; Lee et al, 2017). On the other hand, as discussed in the limitation section, MOOC has some issues, and they could be developed more to have better data sources regarding participants' engagements and reflections, and thus better research opportunities. Adding ways to assess the performance and integrating an intelligent system into the MOOC are some of the solutions for these problems.

This research showed the benefits of a blended learning style in the context of statistics teaching. The findings suggested having PLTs for supporting a deeper and more comprehensive learning of MOOC materials. This learning opportunity, though, could get some more features to better create a community of practice among online participants. For example, adding video conferencing or live chat capabilities in forum panels would allow for synchronous communications, or occasional video-based meetings hosted by the course instructor, which would be an impactful add-on.

Professional learning community (PLC) was chosen as the professional development model for this study. However, some other models could have also been used, such as Japanese lesson study (JLS), for potentially pairing the MOOC with another form of face-to-face professional development. As explained in Chapter 2, JLS provides better opportunities to make changes in practice, because the participants in that model get involved in a highly collaborative and observed process. Nevertheless, this was not possible because the study was limited by time and physical conditions.

PLT participants stated that they got more than they expected from this experience. Several participants admitted that they were doubtful at the beginning, and because of increasing stress in their school requirements, they did not expect to finish the journey. However, they found it very useful for their professional growth, and they were glad to be a part of the project.

Some participants joined a team mistakenly, thinking that it was a requirement for the MOOC; in the end, they found themselves lucky for this misunderstanding.

Participants also stated that it is not common for them to see these opportunities to join online professional development. The participants in high schools (who are not involved in much research) especially need these kinds of opportunities.

An online professional development on teaching statistics should include more lesson plan examples and tasks to give a better sense to the teachers of how to apply the new ideas and approaches about statistics. Statistics is a relatively new subject compared to other mathematics content, and different from other mathematical content. These changes make it more difficult for teachers to decide what to use as tasks in the classes. For example, in mathematics, a problem to teach inverse function does not have to change over time. The context and the formulas stay the same, and that matters in teaching it. On the other hand, the tasks we use for teaching sampling distribution change constantly.

Accessible tools and resources should be included in a MOOC for teachers. Teachers often complain about their physical limitations that do not push their teaching toward new ideas and approaches in teaching statistics. What can a teacher do if he/she does not have a paid data analysis software? He/she needs a free resource that could replace that software. There are lots of tools that could be useful for statistics classes. A great thing about the TSDI MOOC was that it included those free alternatives, both online tools and useful tasks and activities.

A PLT is a great professional development model to help teachers learn together in a shared domain, because it includes a unique experience highlighted strongly in this research: sharing about personal practice. As emphasized in Chapter 2, teachers in the U.S. do not usually share about their teaching with their colleagues in a professional way (Lieberman, 2009).

Teachers should be encouraged to form PLTs in their schools or local area. When they attend the same project as a MOOC about teaching, PLTs would help them to complete the MOOC, help them to understand the MOOC elements better, and encourage them to apply the things they learn. When sharing their personal experiences, asking questions, and listening to others' experiences, teachers become involved in this learning opportunity and tend to change in a positive way.

To better examine the results in teachers' practices, observations should be included as data sources. This would tell us more about the impact of the course. Even though teachers reflected on their perspectives about teaching statistics and their plans about their current or future teaching, observations would be much more objective and consistent with research background, because they represent the researcher's view.

The thoughts about statistics education as separate from mathematics education and considered as its own discipline should be discussed. Almost all PLT participants seemed convinced about the distinction in mathematical and statistical reasoning, and how the teaching philosophies of the two subjects are different. Participants stated that being embedded in mathematics makes it difficult to teach statistics in the way suggested in the MOOC. In some states, statistics is not even a requirement for college enrollment (e.g. NJ), thus students do not pay attention when learning statistics, and teachers do not spend enough time teaching it. Conversely, almost all students go to college realizing that they need to know statistics and they struggle with it. Thus, there should be pressure on stakeholders to take steps to reorganize the place of statistics in high school curriculum.

The TSDI MOOC is highly focused on middle and high school statistics teaching. There are a lot of college statistics teachers showing interest in learning about teaching statistics

strategies to use in their introduction to statistics classes. Participants stated that they expected to see some college instruction examples. In future MOOCs, either those examples could be included, or another MOOC focusing on college statistics teaching could be designed. It is clear that there is a need for these kinds of projects at the college level.

Broader Impact

The implications and recommendations of this study may not be limited to teaching statistics. One strength of this study is the framework it uses. The interconnected model for professional growth (Clarke & Hollingsworth, 2002) was used by focusing on three of its domains to examine teachers' professional growth: external domain, personal domain, and domain of practice. These domains could be identified in any subject using a similar phenomenon. Also, MOOCs are increasing in popularity, and they are more often used for professional development purposes (Kleiman et al., 2013). Knowing that education research has evolved in various subjects to match new technologies and information, MOOCs could be used to help teachers learn about the developments, changes, and new ideas in their subjects. They are accessible for everybody with an internet connection (if they are offered for free). Additionally, using a blended approach to professional development could also be used for other subjects. For example, participating in a MOOC and creating local small professional communities, MOOC participants would benefit from sharing with their colleagues and unpacking MOOC materials together.

Recommendations for Future Research

Research that examines teachers' professional growth in teaching statistics and the effectiveness of participating in a MOOC and PLT has various future directions. According to Golafshani (2003), qualitative research is good if it is repeatable. First, this research could be

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repeated to investigate the findings and whether they were specific to the participants of this year or if they have a broader meaning.

As mentioned earlier, there was no strong evidence about the impacts in participants' teaching statistics practices, because all data was based on participants' self-reports about their practices. This research could (and maybe should) be followed by conducting observations of participants' teaching practices to make stronger claims about changes in teaching practices of participants. Also, observing or collecting data from students of the research participants would be a great opportunity to make stronger claims about the findings. Using pre- and post-statistical tasks and/or tests, and thus collecting data to measure the changes in students' knowledge, beliefs, and perspectives about statistics would enhance the impacts of the findings of this study and could create a bridge between the research about teaching and learning of statistics.

PLT participants' entries in MOOC forum discussions were used in qualitative data analysis to answer the research questions. However, those data included very interesting discussions including both PLT and non-PLT participants, which could be used for answering other research questions about teaching statistics. For example, there were long and rich discussions about teaching probability. Throughout this work, I always felt that probability needed special attention, and it was ignored in this research, because of the nature of the research questions. Another research project could be driven focusing on probability teaching. Another study should be conducted for students' learning of statistics from teachers who participated in this research and used the ideas and approaches recommended by the MOOC. This will contribute to the efforts to improve teaching statistics, and students' learning of statistics.

The TSDI MOOC consisted of both PLT and non-PLT participants. This study did not attempt to compare these two groups; instead, I examined the phenomenon of participating in a MOOC and PLT by collecting data from only PLT participants. Another study should be conducted to examine non-PLT MOOC participants, and to see whether there is a significant difference between the two group in terms of professional growth in teaching statistics.

Teachers would benefit from having a statistics curriculum designed with lesson plans and lots of tasks and activities to give a holistic sense of what statistics teaching through data investigations really looks like if a whole class is designed with it.

Conclusions

The purpose of this study was to identify the effectiveness of a blended professional development effort for the professional growth of teachers in their teaching statistics practices. This study found that participating in a MOOC and in a PLT focused on teaching statistics increased participants' confidence in teaching statistics, positively impacted participants' beliefs and perspectives about teaching statistics, and helped them to better understand how to support students' approaches to statistical investigations. Also, participation in a MOOC and PLT focused on teaching statistics mostly changed the nature of participants planned or self-reported use of various instructional strategies for supporting students' approaches to statistical investigations.

The findings can be used to help statistics education researchers, as well as others in any educational discipline, to design more MOOC and PLT professional development projects to contribute to teachers' professional growth. The findings also can be used to create a common drive to change problematic aspects of statistics in curriculum.

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APPENDICES

Appendix A

Networked Teaching Statistics MOOC Project Leader Interest form

Please complete the following questions to indicate your interest in forming a local professional learning team to engage together in the Teaching Statistics Through Data Investigations online course in Fall 2016.
* Required

Name (first last) *

Your answer

Institution or School context *

Your answer

City *

Your answer

State *

Your answer

How many years have you taught mathematics/statistics? *
0-1
2-4
5-10
10+

Do you anticipate teaching a statistics course or a course that includes statistics content in 2016-2017? *
Yes
No
Not Sure yet

Have you ever participated in a professional development that included a series of small group meetings

extended over several months (this could be in the context of a professional learning team at your school,

or with some other project outside of school hours)? Explain. *
Your answer

Have you ever been a leader in a professional development or taught a course or workshop for other

teachers? *
YES
NO

Informed Consent Form for PLT Leaders

North Carolina State University
INFORMED CONSENT FORM for RESEARCH

Title of Study: **Examining Interactions in, and Impact of, professional development in Teaching Statistics**

Principal Investigator: HOLLYLYNNE LEE

What are some general things you should know about research studies?

You are being asked to take part in a research study. Your participation in this study is voluntary. You have the right to be a part of this study, to choose not to participate or to stop participating at any time without penalty. The purpose of research studies is to gain a better understanding of a certain topic or issue. You are not guaranteed any personal benefits from being in a study. Research studies also may pose risks to those that participate. In this consent form you will find specific details about the research in which you are being asked to participate. If you do not understand something in this form it is your right to ask the researcher for clarification or more information. A copy of this consent form will be provided to you. If at any time you have questions about your participation, do not hesitate to contact the researcher(s) named above.

What is the purpose of this study?

The purpose of this study is to understand how participation in a massive open online course (MOOC) focused on Teaching Statistics with participants across varied geographical locations and in professional learning teams with peer colleagues impacts educators' practices for teaching statistics.

What will happen if you take part in the study?

If you agree to participate in this study, in addition to all work completed in the PLT meetings, you will be asked to complete the following:

- The leaders will be asked to submit pre and post statistics tasks.
- The leaders will be asked to reflect on their experiences after PLT meetings
- PLT meetings will be audio-recorded. After the meeting, the audio file will be uploaded to a secure Google drive location to be shared with the research team.
- The leaders will be asked to participate in a post-project interview.

Risks

Participation is entirely voluntary and a decision whether or not to participate will in no way impact your job. You are free to withdraw from the study at any time. There should be no risks to you from this research.

Benefits

PLT leaders participating in this research may gain a better understanding of the content that is being covered in the interview prompts and survey questions. Since most of the participants are educators who teach statistics in various levels, this information could be helpful to them in their teaching.

Confidentiality

The information in the study records will be kept confidential to the full extent allowed by law. Your name will be removed from all data, including transcripts, and recoded using an identification number. Digital data will be backed up and stored on a password protected external hard drive kept in a locked cabinet. All data will be stored securely on a password protected server or cloud service (e.g., Google Drive). De-identified data may be shared with graduate students who work on this study with the PI. No reference will be made in oral or written reports, which could link you to the study.

Compensation

For participating in this study you will receive $10 Amazon gift card. If you withdraw from the study prior to its completion, you will not receive anything for your participating.

What if you have questions about this study?

If you have questions at any time about the study or the procedures, you may contact the researcher, Dr. Hollylynne Lee, at hstohl@ncsu.edu, or (919)-513-3544.

What if you have questions about your rights as a research participant?

If you feel you have not been treated according to the descriptions in this form, or your rights as a participant in research have been violated during the course of this project, you may contact Deb Paxton, Regulatory Compliance Administrator at dapaxton@ncsu.edu or by phone at 1-919-515-4514.

Consent to Participate

"I have read and understand the above information. I have received a copy of this form. I agree to participate in this study with the understanding that I may choose not to participate or to stop participating at any time without penalty or loss of benefits to which I am otherwise entitled."

Subject's signature_____   **Date**_____

Investigator's signature_____   **Date** _____

North Carolina State University
INFORMED CONSENT FORM for RESEARCH

Title of Study: **Examining Interactions in, and Impact of, professional development in Teaching Statistics**

Principal Investigator: HOLLYLYNNE LEE

What are some general things you should know about research studies?

You are being asked to take part in a research study. Your participation in this study is voluntary. You have the right to be a part of this study, to choose not to participate or to stop participating at any time without penalty. The purpose of research studies is to gain a better understanding of a certain topic or issue. You are not guaranteed any personal benefits from being in a study. Research studies also may pose risks to those that participate. In this consent form you will find specific details about the research in which you are being asked to participate. If you do not understand something in this form it is your right to ask the researcher for clarification or more information. A copy of this consent form will be provided to you. If at any time you have questions about your participation, do not hesitate to contact the researcher(s) named above.

What is the purpose of this study?

The purpose of this study is to understand how participation in a Teaching Statistics through Data Investigation (TSDI) online course with participants across varied geographical locations and in professional learning teams with peer colleagues impacts educators' practices for teaching statistics.

What will happen if you take part in the study?

If you agree to participate in this study, in addition to all work completed in the online course, you will be asked to complete the following:

- The members will be asked to submit pre and post statistics tasks.

- Local PLT teams would engage with the TSDI MOOC-ED materials online that would run for about a 14-week period, accompanied by local team meetings held every 2-3 weeks to discuss materials in course and engage in activities with the PLT Leader. If a member of the research team is present during a meeting, and members generate any artifacts during the meeting (e.g., writing on the board or paper), these may be collected as data.

- The members will be asked to participate in a post-project interview.

Risks

Participation is entirely voluntary and a decision whether or not to participate will in no way impact your job. You are free to withdraw from the study at any time. There should be no risks to you from this research.

Benefits

No specific direct benefits projected from your participation in this research. However, as a participant of the professional development and research, you may be more reflective about your own teaching practices for teaching statistics.

Confidentiality

The information in the study records will be kept confidential to the full extent allowed by law. Your name will be removed from all data, including transcripts, and recorded using an identification number. Digital data will be backed up and stored on a password protected external hard drive kept in a locked cabinet. All data will be stored securely on a password protected server or cloud service (e.g., Google Drive). De-identified data may be shared with graduate students who work on this study with the PI. No reference will be made in oral or written reports, which could link you to the study.

Compensation

For participating in this study you will receive $10 Amazon gift card. If you withdraw from the study prior to its completion, you will not receive anything for participating.

What if you have questions about this study?

If you have questions at any time about the study or the procedures, you may contact the researcher, Dr. Hollylynne Lee, at hstohl@ncsu.edu, or (919)-513-3544.

What if you have questions about your rights as a research participant?

If you feel you have not been treated according to the descriptions in this form, or your rights as a participant in research have been violated during the course of this project, you may contact Deb Paxton, Regulatory Compliance Administrator at dapaxton@ncsu.edu or by phone at 1-919-515-4514.

Consent To Participate

"I have read and understand the above information. I have received a copy of this form. I agree to participate in this study with the understanding that I may choose not to participate or to stop participating at any time without penalty or loss of benefits to which I am otherwise entitled."

Subject's signature_____		**Date**_____
Investigator's signature_____		**Date** _____

Appendix C

Self-Efficacy for Teaching Statistics (SETS) Survey Instrument

Block 3

An important step in orienting yourself to a new professional learning course is reflecting on where you are now and where you want to be as a result of the course.

On this page, we offer you the opportunity to interact with the Self-Efficacy for Teaching Statistics survey. We encourage you to consider how confident you feel to teach topics typically taught in middle school through introductory statistics courses, as well as to set goals for yourself when taking this course. De-identified data will also be used by the MOOC-Ed research team and developers of the survey.

Instructions: There are 44 items on this survey. For each item, rate your confidence in teaching students the skills necessary to complete successfully the task given by selecting your choice 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.

To receive a valid confidence score, you must answer all items. The survey should take 8-10 minutes to complete.

Block 4

Please rate your confidence in teaching students the skills necessary to complete the following tasks successfully:

	Not at all confident	Only a little confident	Somewhat confident	Confident	Very confident	Completely confident
1. Collect data to answer a posed statistical question in contexts of interest to students.	○	○	○	○	○	○
2. Recognize that there will be natural variability between observations for individuals.	○	○	○	○	○	○
3. Select appropriate graphical displays and numerical summaries to compare individuals to each other and an individual to a group.	○	○	○	○	○	○
4. Create dotplot, stem and leaf plot, and tables (using counts) for summarizing distributions.	○	○	○	○	○	○
5. Use dotplot, stem and leaf plot, and tables (using counts) for describing distributions.	○	○	○	○	○	○
6. Create boxplots for summarizing distributions.	○	○	○	○	○	○
7. Use boxplots, median, and range for describing distributions.	○	○	○	○	○	○
8. Identify the association between two variables from scatterplots.	○	○	○	○	○	○
9. Generalize a statistical result from a small group to a larger group such as the whole class.	○	○	○	○	○	○
10. Recognize that statistical results may be different in another class or group.	○	○	○	○	○	○

	Not at all confident	Only a little confident	Somewhat confident	Confident	Very confident	Completely confident
11. Recognize the limitation of making inference (i.e. generalization) from a classroom dataset to any population beyond the classroom.	○	○	○	○	○	○

Block 6

Please rate your confidence in teaching students the skills necessary to complete the following tasks successfully:

	Not at all confident	Only a little confident	Somewhat confident	Confident	Very confident	Completely confident
12. Distinguish between a question based on data that vary and a question based on a deterministic model (for example, specific values of rate and time determines a particular value for distance in the model d = r*t).	○	○	○	○	○	○
13. Identify what variables to measure and how to measure them in order to address the question posed.	○	○	○	○	○	○
14. Describe numerically the variability between individuals within the same group.	○	○	○	○	○	○
15. Create histograms for summarizing distributions.	○	○	○	○	○	○
16. Use histograms for comparing distributions.	○	○	○	○	○	○
17. Compute interquartile range and five-number summaries for summarizing distributions.	○	○	○	○	○	○
18. Use interquartile range, five-number summaries, and boxplots for comparing distributions.	○	○	○	○	○	○
19. Recognize the role of sampling error when making conclusions based on a random sample taken from a population.	○	○	○	○	○	○
20. Describe numerically the strength of association between two variables using linear models.	○	○	○	○	○	○
21. Explain the differences between two or more groups with respect to center, spread (for example, variability), and shape.	○	○	○	○	○	○
22. Recognize that a sample may or may not be representative of a larger population.	○	○	○	○	○	○
23. Interpret measures of association.	○	○	○	○	○	○
24. Distinguish between an observational study and a designed experiment.	○	○	○	○	○	○
25. Distinguish between "association" and "cause and effect."	○	○	○	○	○	○

.

	Not at all confident	Only a little confident	Somewhat confident	Confident	Very confident	Completely confident
26. Recognize sampling variability in summary statistics such as the sample mean and the sample proportion.	○	○	○	○	○	○

Block 5

Please rate your confidence in teaching students the skills necessary to complete the following tasks successfully:

	Not at all confident	Only a little confident	Somewhat confident	Confident	Very confident	Completely confident
27. Describe characteristics of a normal distribution, such as general shape of distribution, symmetry, how standard deviation influences shape, and area under the curve.	○	○	○	○	○	○
28. Estimate percentages via the empirical rule (i.e., percentage of observations within 1, 2, or 3 standard deviations from the mean) using the mean and standard deviation of a dataset which has an approximately bell-shaped distribution.	○	○	○	○	○	○
29. Estimate a specified area under the normal curve using technology or a statistical table.	○	○	○	○	○	○
30. Summarize categorical data using two-way tables (i.e., contingency tables, frequency tables).	○	○	○	○	○	○
31. Calculate and interpret relative frequencies using two-way tables (i.e., contingency tables, frequency tables).	○	○	○	○	○	○
32. Find conditional and marginal frequencies from two-way tables (i.e., contingency tables, frequency tables).	○	○	○	○	○	○
33. Fit an appropriate model (e.g., linear, quadratic, or exponential) using technology for a scatterplot of two quantitative variables.	○	○	○	○	○	○
34. Assess the fit of a particular model informally by plotting and analyzing its residuals.	○	○	○	○	○	○
35. Identify the slope and y-intercept coefficients of a linear model and interpret them in the context of data.	○	○	○	○	○	○

Block 3

Please rate your confidence in teaching students the skills necessary to complete the following tasks successfully:

	Not at all confident	Only a little confident	Somewhat confident	Confident	Very confident	Completely confident

36. Calculate, using technology, the correlation coefficient between two quantitative variables.	○	○	○	○	○	○
37. Evaluate whether a specified model is consistent with data generated from a simulation.	○	○	○	○	○	○
38. Explain the role of randomization in surveys, experiments and observational studies.	○	○	○	○	○	○
39. Describing purposes and differences among surveys, experiments, and observational studies.	○	○	○	○	○	○
40. Evaluate how well the conclusions of a study are supported by the study design and the data collected.	○	○	○	○	○	○
41. Estimate a population mean or proportion using data from a sample survey.	○	○	○	○	○	○
42. Develop a margin of error for an estimate of a population mean or proportion using simulation models.	○	○	○	○	○	○
43. Compare two treatments from a randomized experiment by exploring numerical and graphical summaries of data.	○	○	○	○	○	○
44. Determine if the difference between two population means or proportions is statistically significant using simulations.	○	○	○	○	○	○

Consider some of the topics that you were most or least confident about. What may be some reasons that teachers might be more or less confident in teaching these topics?

Appendix D

Post Meeting Snapshots

Networked MOOCE-d: Post Meeting Snapshot

What is your name?

Your answer

1. What Unit(s) in the TSDI MOOC was this meeting focused on?

Your answer

2. Did you use the suggestions from the PLT guide to plan your meeting?

YES

NO

3. Did you discuss issues/content that was NOT part of the TSDI MOOC in your meeting? If so, please describe.

4. What recommendations, if any, do you have for improving the experience in PLT meetings?

Your answer

5. To what extent do you agree with the following statements?
(1: Strongly disagree… 3: Neutral... 5: Strongly agree)

a.   Meeting helped me learn new things related to teaching statistics

b.   I was enthusiastic for being the team leader of this meeting

c.   PLT members seemed comfortable in this meeting

d.   PLT members seemed to deepen their understanding of the content we discussed

e.   PLT members seemed confused about the content we discussed

f.   PLT members were enthusiastic for participating this meeting

g.   PLT members stated that they plan to apply new methods/strategies in their classroom based on their learning and experience from their participation.

Networked MOOC-Ed Follow-Up Survey for PLT Leaders

This brief survey is to help us evaluate the effectiveness of the Networked MOOC-Ed project for Teaching Statistics Through Data Investigations. Your name is being collected only to match leaders and team members, and will be de-identified after data collection is complete. Your responses will help us improve the ways that we can have small teams engage in online courses.
* Required

Name *

Your answer

1. As a result of your participation in this MOOC-Ed and PLC meetings, did you acquire any knowledge,

skills, and/or resources applicable to your professional practice? *

Yes
No
Not Sure

1.a. Please explain your selection. (open-ended)
Your answer

2. Have you applied any knowledge, skills, and/or resources acquired through your participation in the

MOOC-Ed and PLC meetings to your professional practice?

Yes
No
Not Sure

2.a. Please explain your selection. (open-ended)
Your answer

3. As a result of your participation in this MOOC-Ed and PLC meetings, have you made any change(s) in

your professional practice that have directly affected students (e.g. use of new instructional strategy,

integration of technology, changes to lesson plan, etc.)?

Yes
No
Not Sure

3.a. In detail, please describe any change(s) you have made.
Your answer

[text input box]

4. Were there any specific activities, resources, or supports in this MOOC-Ed and PLC that were critical

in helping you apply what you learned to your practice?
Yes
No
Not Sure

4.a. Please describe your response.
Your answer

[text input box]

5. Do you feel like your team achieved their goals related to teaching statistics by participating in a small

group team as well as the online MOOC?
Yes
No
Not exactly.

5.a. Please explain why you felt goals were met, or if your answer was NOT 'yes', please shortly describe

the constraints you think might have contributed to lack of progress towards meeting goals.

Interview Protocol for PLT Members

Estimated duration: ~45 minutes

Thanks for your participation. Please note that you are free to answer or not answer any questions, and you are free to stop and cancel this interview anytime you want. I will ask you 14 questions about your recent participation in TSDI MOOC (online teaching statistics course) and PLT (small group meetings). Thanks again… Please let me know when you are ready.

Prompts / Questions:

1) Please tell me about your experiences in teaching statistics topics before you participated in these professional development projects?

   a) Have you always thought at the same school?
   b) Have you ever taken any online course before?
   c) Have you been a part of a small professional team before

2) Think about the materials were available in online course... Please tell me a little about the goals you had for your participation in TSDI-MOOC. Why did you want to take this course?

   a) Could you also tell me a little about the goals you had for your participation in PLTs? Why did you want to join a team?

3) Could you tell me how you engaged with online materials?

   a) Did you engage in forum discussions? How did these engagements influence your teaching practices or your perspectives?

      i) what about the videos you watched?
      ii) what about the readings?

4) Please describe the things you have learned throughout your experiences as a TSDI MOOC participant.

5) Please tell me about your small group meeting (PLT), and how you interacted in those?

   a) Throughout the meetings, how have your perspectives about teaching statistics changed or not?

6) Describe the things you learned about teaching statistics throughout your experiences as a PLT member?

I am interested in understanding more about how your participation in the online course and with your small team of teachers may have impacted each other.

7) Describe how your learning from TSDI MOOC participation impacted your engagements in MOOC and PLT community?

8) Describe how your engagements in PLT community with other educators impacted your learning in TSDI MOOC?

I am very interested to learn more about how your participation in the course and small team may or may not have impacted your teaching practices.

9) Do you think your teaching of statistics has been impacted? Please describe how your learning and engagements in TSDI MOOC and PLT community impacted your statistics teaching practices?

10) If we walked into a class where you were teaching a statistics lesson, describe what we would see.

   a) How is what you just described similar to or different from what we would have seen before participating in TSDI MOOC and PLT?
   b) Specifically thinking about the aim of the course, how your course would be different from before? Please consider the course elements as the use of technology; the use of investigative cycle and statistical habits of mind; the use of real and messy data.
   c) As a conclusion of your participation in TSDI MOOC and PLT, are there any significant changes in your perspectives about teaching statistics? Do you think that your understanding of teaching statistics has deepened? Please describe.

11) Think about your experiences… Can you please tell me at least three things were positive for you the areas you think went well throughout the projects? Could you please list three positive areas you observed? Tell me what your opinion about these.

12) Think about the areas you think did not go well throughout the project. Could you please list three negative areas (or areas you were concerned) you observed? Tell me what your opinion is about these.

13) The goal of this project was to positively impact teachers' practices in statistics. How do you think the project could be improved to impact participants' statistics teaching practices more positively?

14) What comments or questions do you have for the research team of this project?

<u>Interview Protocol for PLT Leaders</u>

Estimated duration: ~45 minutes

Thanks for your participation. Please note that you are free to answer or not answer any questions, and you are free to stop and cancel this interview anytime you want. I will ask you 14 questions about your recent participation in TSDI MOOC (online teaching statistics course) and PLT (small group meetings). Thanks again… Please let me know when you are ready.

<u>Prompts / Questions:</u>

1. Please tell me about your experiences in teaching statistics topics before you participated in these professional development projects?
    a. Have you always thought at the same school?
    b. Have you ever taken any online course before?
    c. Have you been a part of a small professional team before
2. Think about the materials were available in online course... Please tell me a little about the goals you had for your participation in TSDI-MOOC. Why did you want to take this course?
    a. Could you also tell me a little about the goals you had for your participation in PLTs? Why did you want to lead a team?

3. Could you tell me how you engaged with online materials?
    a. Did you engage in forum discussions? How did these engagements influence your teaching practices or your perspectives?
    b. what about the videos you watched?
    c. what about the readings?

4. Please describe the things you have learned throughout your experiences as a TSDI MOOC participant.

5. Please tell me about your small group meeting (PLT), and how you interacted in those?

    a. Throughout the meetings, how have your perspectives about teaching statistics changed or not?

6. Describe the things you learned about teaching statistics throughout your experiences as a PLT leader?

I am interested in understanding more about how your participation in the online course and with your small team of teachers may have impacted each other.

7. Describe how your learning from TSDI MOOC participation impacted your engagements in MOOC and PLT community?

8. Describe how your engagements in PLT community with other educators impacted your learning in TSDI MOOC?

I am very interested to learn more about how your participation in the course and small team may or may not have impacted your teaching practices.

9. Do you think your teaching of statistics has been impacted? Please describe how your learning and engagements in TSDI MOOC and PLT community impacted your statistics teaching practices?

10. If we walked into a class where you were teaching a statistics lesson, describe what we would see.

    a. How is what you just described similar to or different from what we would have seen before participating in TSDI MOOC and PLT?
    b. Specifically thinking about the aim of the course, how your course would be different from before? Please consider the course elements as the use of technology; the use of investigative cycle and statistical habits of mind; the use of real and messy data.
    c. As a conclusion of your participation in TSDI MOOC and PLT, are there any significant changes in your perspectives about teaching statistics? Do you think that your understanding of teaching statistics has deepened? Please describe.

11. Think about your experiences… Can you please tell me at least three things were positive for you the areas you think went well throughout the projects? Could you explain why you think so?

12. Think about the areas you think did not go well throughout the project. Could you please list three negative areas (or areas you were concerned) you observed? Could you explain why you think so?

13. The goal of this project was to positively impact teachers' practices in statistics. How do you think the project could be improved to impact participants' statistics teaching practices more positively?

14. What comments or questions do you have for the research team of this project?

Appendix G

TSDI MOOC Unit Feedback Survey

Unit Survey

1   **To what extent do you agree with the following statements?**

	Strongly Disagree	Disagree	Neither Agree Nor Disagree	Agree	Strongly Agree
1. This unit deepened my understanding of the topic(s) addressed.	●	○	○	○	○
2. This unit supported the application of course content to my professional practice.	●	○	○	○	○
3. I felt engaged in this unit.	●	○	○	○	○
4. I put effort in this unit.	●	○	○	○	○
5. I lost track of the world around me while working on this unit.	●	○	○	○	○
6. I was challenged the right amount by this unit (not too much or too little).	●	○	○	○	○
7. I thought time passed quickly while working on this unit.	●	○	○	○	○

2   **What recommendations, if any, do you have for improving the user experience in this unit (e.g., navigation, visual design, unit organization, etc.)?**

3   **Approximately how many hours did you spend on this unit's activities?**

- ○ 1-2 hours
- ○ 3-4 hours
- ○ 5-6 hours
- ○ 7-8 hours
- ○ more than 8 hours
- ● No answer

Close this window

Appendix H

TSDI MOOC End-of-Course Feedback Survey

EOC Survey

Page 1

1   As a whole, how effective was this MOOC-Ed in supporting your personal and/or professional learning goals?

Very Ineffective	Ineffective	Neutral	Effective	Very Effective
○	○	○	○	○

2   What was the most valuable aspect of this MOOC-Ed in supporting your personal or professional learning goals?

[text editor box]

3   To what extent do you agree with the following statements?

As a result of my participation in this MOOC-Ed, I have improved my knowledge and/or skills related to...

	Strongly Disagree	Disagree	Neither Agree Nor Disagree	Agree	Strongly Agree
1. understanding of how to engage students in a statistical investigation process.	○	○	○	○	○
2. understanding of how students reason with data to make evidence-based claims.	○	○	○	○	○
3. using a framework to guide my planning and teaching of statistical investigations to promote deeper data explorations for my students.	○	○	○	○	○
4. using rich data courses to support investigations of questions that are of interest to me and my students.	○	○	○	○	○
5. using dynamic tools to visualize and analyze data.	○	○	○	○	○

4   Overall, how effective do you feel this MOOC-Ed was in preparing you to make positive changes in your professional practice?

Very Ineffective	Ineffective	Neutral	Effective	Very Effective

5 * Have you attempted to make any changes in your professional practice as a result of your participation in this MOOC-Ed?

○ Yes
○ No
○ Not Applicable

6 In what ways, if any, do you anticipate applying the knowledge, skills, and/or resources you acquired from this course to your professional practice?

7 Please describe any changes you have made to your practice, including how you have applied the knowledge, skills, and/or resources you gained in this course.

8 * Did you attempt to earn a micro-credential for this MOOC-Ed?

○ Yes
○ No
○ I'm not sure

9 Why did you choose to pursue a micro-credential for this course?

10 In what ways, if any, did the micro-credentialing process impact your professional practice?

11 Why did you choose not to pursue a micro-credential for this course?

12   To what extent do you agree with the following statements?

MOOC-Ed Micro-credentials are a valuable tool for...

	Strongly Disagree	Disagree	Neither Agree Nor Disagree	Agree	Strongly Agree	I Don't Know
1. engaging in professional learning with an increased level of rigor.	●	○	○	○	○	○
2. promoting significant changes to my instructional practice.	●	○	○	○	○	○
3. communicating my professional competencies with others.	●	○	○	○	○	○
4. personalizing my professional learning experience.	●	○	○	○	○	○
5. facilitating collaboration and communication with other educators.	●	○	○	○	○	○
6. motivating me to pursue additional learning opportunities within or beyond the MOOC-Ed.	●	○	○	○	○	○

13   What recommendations do you have for making this course more valuable to future participants (e.g., other resources, additional features, activities, etc.)? Please explain.

14 *   Were you able to complete all of the activities that you wanted to complete in this course?

○ Yes   ○ No

15   Please explain.

16   Approximately how many hours per unit did you spend on MOOC-Ed activities?

○ 1-2 hours per unit
○ 3-4 hours per unit
○ 5-6 hours per unit
○ 7-8 hours per unit
○ more than 8 hours
● No answer

17 *   MOOC-Eds are often used as part of a professional development blended learning model. Which of the following best describes any peer groups with which you participated and/or collaborated outside of this MOOC-Ed?

○ I did not participate and/or collaborate with anyone outside of the MOOC-Ed
○ School or district-based professional learning team
○ Online professional learning network (e.g., Twitter, Facebook group)
○ Informal group of colleagues
○ Other: (please describe):

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