Team Teaching for Discourse: Perspectives of Instructors and a Student in an Online Probability and Statistics Course for Preparing Mathematics Specialists

V. Rani Satyam
Virginia Commonwealth University
vrsatyam@vcu.edu

Kristina C. Anthony
Virginia Commonwealth University
anthonykc@vcu.edu

Madhumita Basu
Virginia Commonwealth University
basum@vcu.edu

Monica Swoyer
Manassas City Public Schools
mswoyer@mcpsva.org

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Abstract

Team teaching is a form of collaborative work where teachers plan lessons and/or teach together. We discuss the strengths of discourse in the planning stage for an intensive, team-taught, three-week probability and statistics course for mathematics specialists as a way to create and sustain a sense of community and show multiple perspectives in an online course. We delve into two cases of lessons—one about stem-and-leaf plots and another on averages—to describe the interactions of and reflections from three online instructors and a preparing mathematics specialist across the phases of planning, enactment, and the resulting student learning. The conversations about our understandings of probability and statistics concepts that arose between the three instructors with differing arenas of expertise—a mathematics educator, a probability instructor, and an expert teacher—often were predictors of conversations that occurred among candidates during class. Through these mirrored conversations, we were able to build off of and expand candidates' conceptions regarding probability and statistics. We argue that when preparing mathematics specialists, having a team with diverse domain expertise but enough overlap to push each other's thinking was crucial to successful planning and enactment in the team teaching setting.

Keywords

team teaching, statistics and probability, online learning, social learning

Mathematics specialists have been and continue to be needed to support teachers (Dossey, 1984; Fennell, 2006). It is crucial, then, that teacher educators provide robust learning opportunities for specialists so that they can, in turn, provide accurate and effective learning experiences for classroom teachers. This reflection on a mathematical content course as described by one candidate (a preparing mathematics specialist) illustrates the importance of experience and community in an online environment:

> Over the duration of the program, and this course, I found myself explaining that I was in an online program, but it really wasn't "online-online." It could be because previously my perceptions of online learning were reading pages and pages, posting to a discussion board, and responding with very little *real* discussion with anyone. Instead, for this program, I had to be "in class." The whole class and small group experiences took my online learning experience to the next level. Knowing my classmates and hearing their thoughts, ideas, and explanations improved my understanding a hundred times over.
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> Taking time to reflect on my experiences made me realize that what took place during each class was not by chance but rather, the direct result of careful planning and negotiating among teams of instructors. The experiences, learning, and discussions that made our probability and statistics course rise above other courses can be attributed to the diverse group of instructors who not only broadened the view of statistics for their students, but also for themselves. (M. Swoyer, personal communication)

We argue that discourse in the planning phase of team teaching with three instructors who had differing areas of expertise was vital to fostering this sense of community among candidates to bolster their learning.

This paper explores the strengths of discourse within a team teaching approach in an online synchronous probability and statistics course as part of a mathematics specialists' program. Through reflections from the instructional team and a candidate, we examine the impact of an experientially diverse instructional team on the course design process, enactment of lessons, and student learning. We discuss two pivotal scenarios from the course development phase and the online classroom about stem-and-leaf plots and the meaning of the word "average" to illustrate how instructors with differing yet overlapping expertise provide different perspectives that lead to rich class discussions that are beneficial for mathematics specialists.

Literature Review

Team teaching is a form of collaboration among teachers, which can take on various forms: (a) division of responsibilities; (b) cooperative planning but individual instruction; or (c) cooperative planning, instruction, and assessment (Sandholtz, 2000). Here, we use the term "team teaching" to refer to this last version, as it is the most collaborative. Under this view, both students and instructors themselves are exposed to different perspectives (Harris & Harvey, 2000). Effective team teaching requires the honest exchange of ideas between instructors, a clear understanding of individual roles in the team, and adequate time for planning together (Shibley, 2006). Though conversations on content are important, the negotiating of pedagogical decisions that occur during planning is also important for setting the stage for learning.

Just as the curriculum development process in a team teaching environment should provide ample opportunities for instructor interaction, the structure of an online course should also actively engage students. We view learning from a classic social constructivist standpoint, where interactions promote thinking and reasoning through language (Vygotsky, 1978). Online instructors must then plan opportunities for meaningful exchanges between students to foster understanding; social interactions between students and between teachers and students are key for learning in an online classroom (Hill et al., 2009). We use the term *learning community* in this paper to refer to a group of people coming together with shared goals and norms for learning. Even through an online medium, members of a learning community (teachers and students) all share the responsibility to contribute to the overall class learning experience (Harris & Harvey, 2000; Hill et al., 2009).

Context of the Course

The online course, co-taught by three faculty members from Virginia Commonwealth University, was a three-week, online probability and statistics course. The candidates in the course had been together for two years and were comfortable with the online structure, so the candidates knew and were accustomed to active participation. The course covered K–8 statistics and probability concepts. The course was guided by the five practices for orchestrating mathematical conversations: anticipation, monitoring, selecting, sequencing, and connecting (Smith & Stein, 2011). Using these principles, pre-session work completed by candidates prior to in-class meetings and delivered through a course management system (e.g., Blackboard) included case studies, independent activities, and small group discussions to facilitate class sessions. During in-class meetings, through a video conferencing tool (e.g., Blackboard Collaborate), candidates worked independently and in small groups on tasks; their group work was then selected, sequenced, and shared for whole group discussion.

Instructor and Candidate Backgrounds

Kristina is a mathematics educator with over twenty years of experience in the PK–12 and university settings. Her experiences include working with K–8 students and pre-service and in-service teachers. Kristina brought her pedagogical and content knowledge from PK–12 teaching and her prior experience teaching for the online math specialists program to the instructional team.

Mita is a statistics educator with over fifteen years of experience teaching statistics full-time at the undergraduate and graduate levels. She brought expertise with statistics to the instructional team. This was her first time team teaching, as well as teaching an online course on statistics and probability.

Rani is a mathematician and mathematics educator. She brought a focus on student thinking to the instructional team. She has four years of experience teaching pre-service teachers in person. This was her first time teaching in-service teachers, synchronous online courses, and team teaching.

Monica is an elementary school educator with thirteen years of teaching experience, and she is now serving as a K–4 mathematics coach. Prior to joining the mathematics specialist cohort, she participated in a literacy specialist cohort at another university and was a K–4 mathematics interventionist for four years. She was a candidate enrolled in the online probability and statistics course.

Impacts of Team Teaching on Enactment

We first describe the course design process and then two episodes that occurred during class. These episodes show how conversations across the instructional team during course development helped with anticipating and connecting to mathematical and statistical thinking during class online. For each case, Monica provides her reflection as a student. Through reflection, which is vital to improve professional practice (Hart et al., 1992), we illustrate how discourse before and during an online class can impact the learning experience for all.

Course Design

We, the instructors, co-developed the course over a six-week period prior to the first class. We drew on pre-existing materials from the in-person version of the course as had been taught by others and modified them for the online medium. In general, Kristina brought the teacher pedagogy, Rani drew out children's thinking, and Mita provided ways to push candidates' probability and statistics thinking. As a result of our differing lenses, we integrated into the class activities such as reading case studies of children's thinking, watching classroom videos, doing rich mathematical and statistical tasks, and playing probability games.

However, the curriculum design process was more than the sum of its individual instructors' contributions. The group talked about all instructional decisions as we considered what our different perspectives could bring to the class. Individually, we completed all class activities prior to our team instructor meetings in which we expanded each activity by focusing on the big ideas and how to differentiate across the candidates' grade levels. For example, in one activity, Mita and Kristina both looked at the same graphical representation of students and the number of teeth they had lost, and they each viewed the data differently. Mita interpreted the graph as asking, "How many students lost a given number of teeth?" Meanwhile, Kristina, coming from an elementary perspective, thought it was asking, "How many teeth did a given student lose?" This conversation led us to realize these were two different ways to interpret one graphical representation, that interpretation was influenced by grade level, and that it all depended on the question one was asking.

Noticing how our conversations like the one above pushed our thinking, we chose to focus on the activities that pushed each of us in our mathematical thinking to be a driving force for class discussion. Our differing views were rooted in how probability and statistics courses vary; our conceptions were often based on our own learning experiences. Learning to question each other's thinking and reflect on different mathematical and statistical views became a common occurrence during planning.

The *Statistics: Modeling with Data* casebook (Russel, Schifter, & Bastable, 2018), part of the *Developing Mathematical Ideas* series, was our primary source for supporting candidates in working with mathematical concepts and learning to support the development of student understanding. Using the text as the foundation for the course, we planned for a variety of structures: out of class individual and small group pre-session work, in-class direct instruction, individual work, small group work, and whole group discussion. The course structure purposefully led candidates to engage in discourse within different groups, drawing on each person having years of rich and diverse experience to share.

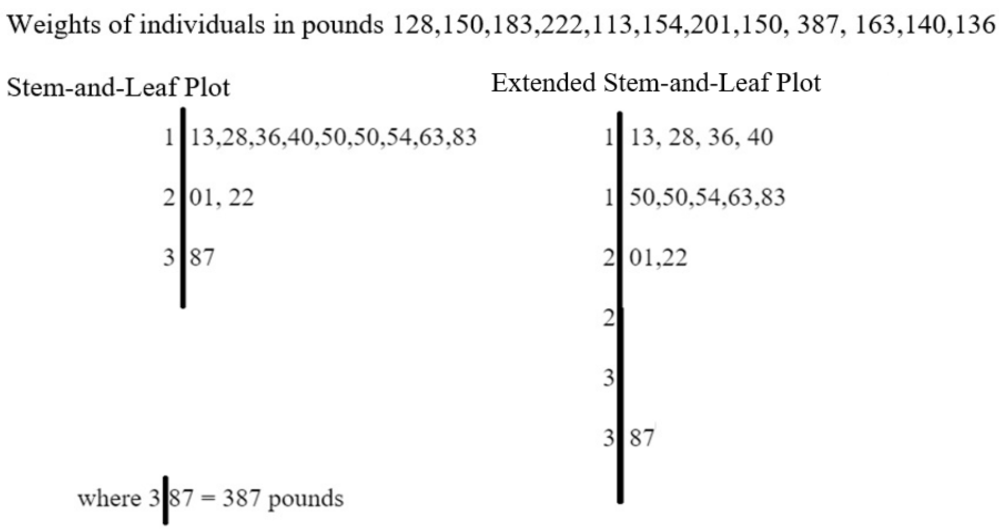
Case A: Stem-and-leaf Plots Discussion

Conversations during Planning

A key idea throughout the course was understanding how to appropriately represent a dataset as a graphical display. One course activity that centered on this concept asked candidates to create a stem-and-leaf plot. Kristina and Rani knew to look at each number, separate the number into a "stem" and a "leaf," and then organize the stems and then the leaves from least to greatest. Mita shared an extended stem-and-leaf plot for large datasets with a small range, which pushed Kristina's and Rani's K–12 understanding. She further shared that stem-and-leaf plots should have anywhere between 6–20 stems. Thus, if it has fewer than 6 stems, it is best to "split the stems" so that there are more stems. An extended stem-and-leaf plot (see Figure 1) better shows the shape and distribution of data, which in turn allows one to better describe and understand the data. Mita's background expertise was crucial, as this idea was new to Kristina and Rani. But upon further conversation, it made sense when thinking about real-world data and the query: Given a particular "research" question, what would be the best way to display the data?

Figure 1

Standard Stem-and-Leaf and Extended Stem-and-Leaf Plot



Note. The diagram on the left depicts a standard stem-and-leaf plot, drawing from the data at the top. The small number of stems and the multiple leaves for the "1" stem indicate the data may be better illustrated through an extended stem-and-leaf plot (on the right).

Our conversations as an instructional team led us to recognize that K–8 teachers are (like Kristina and Rani) rarely exposed to large datasets, and so students are also rarely exposed to large datasets in the classroom. At first, we questioned the benefit of sharing the extended stem-and-leaf plot: Kristina grappled with it from a K–8 perspective while Rani did from a mathematician's perspective. Mita, however, showed us its benefits for even moderate sized datasets. We decided that understanding a stem-and-leaf plot involved more than just the construction procedure but also how this graphical display would be used in a research context and thus real-life applications. Sharing this idea would lead the candidates to understand how graphical displays can tell the story of the data: There are different ways to depict a data set, and the shape of the distribution of a data set changes depending on the type of stem-and-leaf plot one constructs.

Kristina and Rani's previous understandings of stem-and-leaf plots allowed the team to predict and relate to where the candidates' beginning understanding may be. This allowed the team to carefully and intentionally design the instruction to move the candidates to this deeper understanding of stem-and-leaf plots.

Enactment

Conversations around stem-and-leaf plots led to a pivotal moment in the first class. We gave candidates a data set and asked them to create a stem-and-leaf plot in small groups. The groups were intentionally a mix of elementary and middle school teachers, as we knew some candidates may not be familiar with this type of graph. We intended for each small group to be a learning community, to share and support each other in their mathematical thinking. Once small groups had completed their stem-and-leaf plots, we shared their representations in whole group discussion. All groups created a standard stem-and-leaf plot with little debate.

Mita shared pictures of a standard and an extended stem-and-leaf plot with split stems for the same data set as seen in Figure 1. She asked the class for their thoughts; many candidates instantly raised their hands and asked questions through the chat feature in the online classroom. This was the first sign that candidates' thinking had been perturbed. Mita, as the statistician, addressed each question, but because of our prior conversations, both Rani, as the mathematician, and Kristina, as the PK–12 teacher, were actively engaged in the conversation. Kristina and Rani shared with the candidates their misgivings and questions about splitting the stem during the planning stage but supported Mita. We explained that the conversations we had as the instructors during the planning stage uncovered our own misconceptions about stem-and-leaf plots, which we now shared to support candidates' questions and misconceptions. This helped the candidates open up even more with the entire class about their current thinking. Then we, as instructors, helped them extend their understanding. By purposefully allowing candidates to question and argue their thinking and by sharing with them our own (lack of) understanding, we supported the candidates in understanding graphical displays from a broader context than a K–8 classroom, further solidifying our online learning community.

Student Perspective

This activity helped solidify my understanding of concepts like stem-and-leaf plots by allowing me to articulate what I understood to others. I had a narrow understanding of the mathematics being explored until I heard perspectives offered by my classmates. There were other times during the discussion when I was the "group expert" and explained the ideas I understood to my classmates. The instructors may not have seen how powerful that type of small group discussion would be for the candidates if they themselves had not grappled with their own understandings of stem-and-leaf plots as they planned and designed our experiences for the session.

Case B: Averages Discussion

Conversations during Planning

Mathematical language played an important role in course development, as we saw in our lesson about averages. Words such as *average* have both a mathematical and everyday meaning.

One activity had candidates identify the average of five numbers in a set, e.g., 6, 7, 7, 7, and 8. Mita and Rani both thought of *average* and *mean* as synonyms, coming from statistical and mathematical perspectives. However, Kristina thought of the mode, arguing that for this set of numbers, the word average might imply to children the number that appeared the most. The mean, median, and mode were all mathematically the same in this problem (seven), so we looked at several variations of five numbers where the mean, median, and mode were the same or different. For example, in the case of 5, 7, 8, 9 and 12, each of us said we would calculate the arithmetic mean for the average based on the relationship of the numbers. We began to notice that depending on the numbers or context of the numbers, our personal choice of whether to use the mean, median, or mode to represent the average changed.

As an instructional team, we had varying interpretations of the meaning of average; our different expertise had come into play. Kristina shared that in the Virginia Department of Education's (2016) curriculum framework for fifth grade mathematics, the mean, median, and mode were all referred to as types of averages. The term *arithmetic average* is used to refer to the mathematical mean. We were forced to justify our thinking to each other, and these conversations helped us recognize the importance of providing a non-judgmental space for the candidates to have the same conversations with each other. Our roles as instructors were to support the candidates in justifying their thinking, so we planned for small group discussions across different grade levels to deepen their use and understanding of mathematical language in K–8 classroom discourse because it would push their thinking.

Enactment

In pre-session work, we prompted participants to think about the word *average* within the assigned case studies, which focused on K–8 students making meaning of the word in conversation and within mathematical content. Next, small groups found the average of various data sets consisting of five numbers. Similar to what had occurred during instructor discourse, when candidates shared their thoughts, the idea of average potentially referring to the *middle* arose. This could come from a person thinking about height, where there are several people shorter or taller than the middle height. Average could also refer to *normal* if thought of as what you see the most in a group. Several participants shared that average meant the *mean* of the data set, thinking about mathematical definitions.

To our surprise, mirroring that of instructor conversations, candidates talked about how K–8 students need opportunities to explore mathematical language in context. The candidates drove the conversation forward on their own without instructor prompting. They sequenced their conceptions of the word average by grade levels. They then moved from mathematical language to representations which supported the class development of mathematical knowledge and addressed misconceptions. Unplanned, our role changed that evening from facilitating to reinforcing and questioning candidates' thoughts. Our prior conversations as an instructional team prepared us for this unexpected turn. Because we had experienced as an instructional team the openness in interpretation of the word average and ensuing confusion, we were better able to support the candidates as they experienced this in real time. Mita, for example, nudged candidates to reflect on the statistical idea that mean and median are the only real measures of center, not mode. This idea challenged the candidates' existing notions of measures of center. But because each of the instructors jumped in organically to add their thoughts, there was a conversational tone to the lesson, with little tension. Ultimately, this back-and-forth in discourse led candidates to a higher level of understanding.

Student Perspective

The discussions around the idea of average and what average meant in different contexts were insightful. I spent a good part of that class building this common understanding and definition of average with the other candidates and instructors. There was definite discomfort in our small groups when some candidates' clarity of the word average was challenged. These conversations made me more willing to look to and learn from my classmates to enhance my learning. I did not realize at the time how powerful my social connection to the other candidates was, nor how intentional the planning for these social connections was as well. I attribute my success and growth in statistics and probability to the intentional design and enactment of the course.

Discussion

Through these two episodes, we have shown how team teaching was beneficial in both the planning and enactment of an online statistics and probability course for preparing mathematics specialists. The conversations within the instructional team were crucial for effective team teaching, as they were often precursors to conversations that occurred in class. This meant we, as instructors, could anticipate candidates' thinking prior to the online meetings, so we could facilitate more productive conversations (Smith & Stein, 2011). Instructors were also able to organically chime in when each other was speaking, to add and build off one another's perspective. This normalized different ways of thinking about concepts and provided a more conversational atmosphere, which invited candidates to join in as well.

We recommend team teaching for all content courses for mathematics specialists in order to draw out rich conversations that specialists will likely witness among teachers and students in the classroom. We especially recommend team teaching for probability and statistics, as this content area brings in ideas from different disciplines and is a struggle for many people. Each of the instructors professed that we would team teach again, with each other and with others.

In terms of recommendations, we believe the facts that we were all new to teaching the course online and that we had set norms for working together were crucial for our success. We were all on equal footing in creating material for a new course together. Second, it is beneficial to co-develop (at least some) lessons together, rather than divide the work, for the sake of the discourse that ensues. Each instructor was aware of all the content, as we had collectively decided what to include and why. This drew out conversation about the content, which led to each individual instructor knowing each other's thoughts, and so we were prepared to build off what one another said in a natural way during class.

This work has implications for the importance and structuring of team teaching in order to develop robust learning experiences for mathematics specialist courses. An instructional team with different background expertise, where each instructor fulfilled a role and was an expert in their domain but with slight overlaps to push each other's thinking, was crucial. Together, we formed a learning community, questioning and sustaining each other, even before the first class meeting. This instructor learning community then supported the creation and strengthening of candidate learning communities. This prior engagement allowed us as instructors to be active in all conversations as we knew what others were thinking, and the candidates' discussions often mirrored ours. It also allowed us to share a common vision for the candidates' online experience.

This work also illustrates the importance of a social environment and interaction for effective online instruction. Monica described how she saw our roles within the community at the end:

> Reflecting on the experience, I can see how I relied on each of the instructors differently during this course. I quickly learned to listen closely when it was Mita's turn to share; she was going to share her vast knowledge of probability and statistics. Rani helped to clarify the big ideas being explored. Lastly, I relied on Kristina's ability to break down the learning into manageable chunks, as I am accustomed to doing in my own elementary teaching experience. (M. Swoyer, personal communication)

By team teaching, our conversations and interactions support our specialists' learning, and through them, we serve communities of teachers across Virginia.

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Author Note

All work was shared equally among the co-authors. Correspondence concerning this article should be addressed to V. Rani Satyam, Department of Mathematics & Applied Mathematics, Virginia Commonwealth University, 1015 Floyd Avenue, Box 842014, Richmond, Virginia 23284. Email: vrsatyam@vcu.edu

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