

Modeling equity using multiple technologies for teaching statistics with preservice teachers

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Mathematical knowledge for teaching requires strong content knowledge, yet statistical content knowledge is often overlooked in elementary teacher education. Many elementary preservice teachers (PSTs) struggle with core statistical concepts like mean and median, and even those with strong content knowledge may lack effective teaching strategies. This study describes the design and implementation of a statistics lesson aimed at promoting equitable learning experiences using technologies such as GeoGebra and Padlet. Data collected included the mathematical work and reflections of 27 PSTs, video recordings of the lesson, and observers' field notes; all were analyzed using qualitative methods. Analysis showed that technology-supported statistics learning encouraged understanding of statistical concepts for PSTs as learners, and that reflecting on pedagogical strategies used in the lesson allowed PSTs to analyze the lesson as future teachers. These findings underscore the need for teacher preparation courses that emphasize both content and pedagogy in teaching statistics.

INTRODUCTION

Understanding statistics and data literacy is increasingly important for making sense of issues and making informed decisions in our daily lives. This has been an international focus for decades. The main goal of the International Statistical Literacy Project (ISLP) initiated by the International Association for Statistical Education (IASE) is to contribute to promoting statistical literacy across the world. In 2024, the National Council of Teachers of Mathematics (NCTM) collaborated with major organizations (NSTA, ASA, NCSS, and CSTA) to release a joint position statement on data science: “Data science bridges disciplines and thus should be introduced and taught across the curriculum in K-12 schools to help develop informed users of data” (NCTM, 2024, paragraph 4). To do so, teachers must have strong content and pedagogical knowledge in statistics and data literacy.

Ball et al. (2008) conceive of mathematical knowledge for teaching as a constellation of specific types of mathematical content knowledge including Specialized Content Knowledge, Common Content Knowledge and Horizon Content Knowledge. In statistics, teachers need to possess a deep understanding of concepts such as context, uncertainty, variability and randomness, which are distinct from other areas of mathematics (Franklin et al., 2015). Statistics may be the most overlooked mathematical content in elementary teacher education programs (Sutherland et al., 2024). Groth and Bergner (2006) concluded that elementary preservice teachers' (PSTs) knowledge of mean, median, and mode is often fragile, mirroring that of students. PSTs struggled with “mastering and applying the procedures for measures of center; recognizing mean, median, and mode as measures of what is central or typical in a set of data; and being able to work flexibly with a number of different measures of center” (Groth & Bergner, 2006, p. 57).

Even when teachers have strong statistical *content* knowledge, their *pedagogical content* knowledge may be scant (Mickelson & Heaton, 2004). Mickelson and Heaton's case study showed the need for strong pedagogical content knowledge: “What is interesting and perplexing is that Donna exhibits strong statistical reasoning skills in one contextual setting, but that same knowledge or skill does not necessarily transfer to all of her teaching work with children” (p. 348). This requires special reasoning, for instance, where teachers need to recognize “when and how context matters across all tasks of an investigation” (p. 350). Cobb and McClain (2004) proposed design principles to support the students' statistical reasoning by listing special characteristics of the activities, data analysis tools and classroom discourse. Franklin et al. (2015) emphasize that the preparation of elementary teachers in statistics should help PSTs:

- build content knowledge and statistical reasoning skills,
- understand how statistical concepts build upon each other from elementary to middle grades and connect to other elementary school subjects,

- "develop pedagogical content knowledge necessary for effective teaching of statistics. Pre-service and practicing teachers should be familiar with common student conceptions, content-specific teaching strategies, strategies for assessing statistical knowledge, and appropriate integration of technology for developing statistical concepts" (p. 14)

This paper documents and analyzes the design and enactment of a lesson using multiple technologies to model equitable mathematics teaching and learning of statistics in a college mathematics class for elementary PSTs. One key strategy to support PSTs' learning about equity is to make visible the strategies that help increase equity in the classroom during their preparation programs through teacher modeling (Graham, 2020). Graham and McDuffie (2023) shared how a practice-based methods course used activities such as equity-based lenses for video analysis, live lesson observations, and case study analysis to support PSTs' developing awareness of equity. Acquah et al. (2020) echo the idea of modeling as "a fruitful strategy in teacher education" (p. 122) and prompted preservice teachers to notice and reflect on the modeled strategy for their future teaching. Little and Bartlett (2010) note that "the empirical research literature that focuses on preparing teachers to work in classrooms with a diverse population of students, or with students whose backgrounds are unlike their own, suggests this to be a task of considerable magnitude" (p. 295). They shared some promising strategies, including one "where prospective teachers are engaged in activity that requires them to delve deeply into their own assumptions and beliefs while also developing orientations and practices that will help them succeed" (pp. 295-296).

To extend this line of inquiry, we studied PST's reflections following a statistics lesson, delivered by one of the authors which included technology and pedagogical strategies designed to promote equity. Our research question is: In a lesson using multiple technologies for teaching statistics with understanding, what do PSTs notice, as learners and as future teachers?

CONCEPTUAL FRAMEWORK

In our work, we understand instruction as a dynamic process that necessarily includes content, a teacher, and students, taking place in environments. These four elements are not only in constant flux in instruction, but on their own can shift and change. This has been captured by Cohen et al. (2003) as instruction as interaction or by Schwab (1983) as the four commonplaces. We conceive of teacher learning as two "instructional triangles" layered one upon the other: teachers as the learners, in their own instructional triangle, viewing the instructional triangle of students learning content with a teacher in environments. In this double-layered model, the content in the teachers' instructional triangle is teaching itself. These models are shown in Figure 1 below. The vertices of the instructional triangles shown become vantage points for considering features of a lesson: the content, the learners, and the teacher, all in a number of environments that affect the dynamics of the triangle in motion.

Our work is also framed by a press for equitable outcomes for learners. The press for equity can be understood as one of the environments that contains and constrains the instructional triangle. Equitable outcomes have long eluded mathematics learning in the United States (cf. Hanushek et al., 2020), and the lesson described in this paper was designed to investigate how to intervene on this persistent challenge in mathematics education.

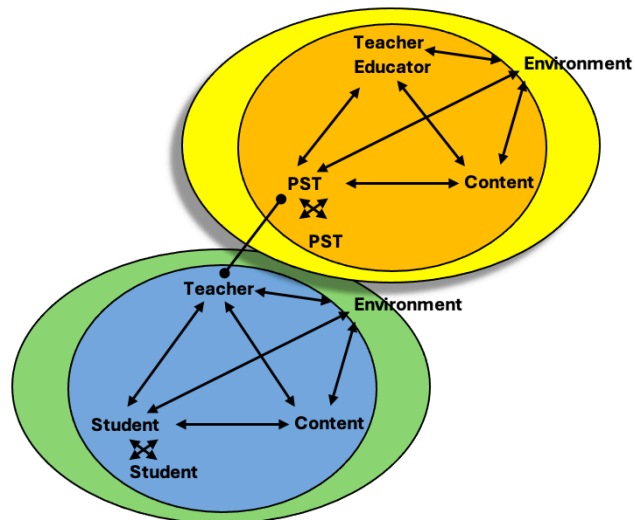


Figure 1. The Instructional Triangle (Cohen et al., 2003), adapted for teacher education.

METHOD

To study how PSTs might learn to teach statistics and data literacy in a more equitable fashion, a lesson was designed involving measures of central tendency. While central tendency is a cornerstone topic for statistics, the research goal of this study was not based on this content goal, but rather how teacher educators can better support PSTs to develop statistical pedagogical knowledge. The lesson was characterized by several elements: the use of technology to shift the emphasis away from calculating mode and median towards a more intuitive understanding of these measures; the inclusion of a real-world use of mean and median to highlight the relevance of these measures; and the use of conveyance technologies for sharing mathematical ideas publicly. These elements were selected to promote equitable learning in the lesson, a lesson that was intended to engage PSTs in equitable learning for themselves as learners, and at the same time model equitable instruction that they might carry out as future teachers. The lesson was comprised of five components:

1. A launch that provided a context for how measures of central tendency can help us understand things we care about. The PSTs interacted with the web-based [Dollar Street](#) which we conjectured would offer a captivating context (The PSTs were able to view pictures/videos from 264 families in 50 countries) and a sizeable collection of data (monthly income).
 - a. A quick review of measures of central tendency
2. An exploration with an interactive [GeoGebra applet](#) without any context:
 - a. The PSTs created different data sets each with equal mean and median by moving data points on a dot plot
 - b. The PSTs constructed data sets in which the median better represented a typical value, but the mean did not
3. A whole-class discussion based on shared postings on Padlet for both exploration tasks
4. A brief contextualized mathematics task at the end of the lesson: Using a data set of ten salaries in a fictional business, where a few workers earned significantly more than the other workers, the PSTs were asked to create different messages about what workers earn at the company, using the median and the mean.
5. A post-lesson reflection for the PSTs to consider the lesson both as learners and future teachers

The three main tasks of the lesson were sequenced to begin first with authentic real-world data exploration, followed by a context-free hands-on mathematical task, and ending with a contextualized mathematics task to solve. The real-world data in Dollar Street situated the lesson so that PSTs visited households around the world (virtually) to see how much they earn and how they live. The aim was to show how data can be aggregated, and how measures of central data serve sensemaking. In the second main task, PSTs would move dots in an app to experiment with mean and median, without any context. The final task was for PSTs to apply newly acquired understanding of mean and median to answer a real-world question. As learners, the PSTs commented on the context (“a good way to shift my

perspective on life outside of America while tying math into the lesson”); as future teachers, they began to imagine ways that context could connect various disciplines and provide global awareness and diversity (“can help teach about global awareness and diversity”).

Data collected and analyzed for this study included the statistical work of 27 PSTs, their reflections on the lesson, and field notes from three teacher educators. Data were analyzed using qualitative methods informed by the conceptual framework. The research team coded data using a mixed methods approach (Creswell, 2014) and codes were grounded in the data and informed by the vertices of the instructional triangle (Cohen et al., 2003). Initial coding was done by the research team members individually. Following that, the team met to discuss the codes and to check for agreement across the data sources. This established categories, patterns, and themes.

RESULTS

Our analysis of an earlier version of the lesson, delivered in a secondary classroom, led us to conclude that doing mathematics with understanding, aided by technology, supported the development of a positive mathematical identity, a sense of mathematical authority, and growth of student agency. Therefore, we wanted to model these in a teacher education class to study what PSTs notice as learners and as prospective teachers. Table 1 lists our pedagogical goals, the elements we incorporated into the plan and enacted during the lesson, and the analysis of the PSTs’ reflections and work.

Table 1. PSTs’ Noticing.

Pedagogical Goal	Lesson Element	PSTs’ Noticing	
		As a Learner	As a PST
Differential uses of context	Mix of contextual and context-free tasks	“The Dollar Street was one of my favorite tools to use as a student. I’ve never seen or used a program like this, and it was such a good way to shift my perspective on life outside of America while tying math into the lesson.”	“Dollar Street can help teach about global awareness and diversity.”
Student active engagement towards mathematical understanding	Using math action technology (GeoGebra)	“...the visual representation [of GeoGebra] helped me understand the concept more clearly.”	“It made it a lot more interactive and interesting...I will definitely use [GeoGebra] in the future.”
Learning through mathematical discussion	Small group work followed by whole class discussions	“The use of technology in the classroom gave me access to work with my peers in a whole new way. We could easily share our thinking with Padlet.”	“Padlet supports collaboration and lets students share their ideas in a fun and organized space. However, there can be challenges, like access.”
Expanding participation towards the creation of equitable learning	Making PSTs’ work visible via conveyance technology (Padlet)	“Padlet was nice because we could see what the whole class work was rather than just our table groups or the few people that shared with the class.”	“I think it does create pedagogical challenges...some students may be familiar with technology while others struggle. That said, our class...made connections to Dollar Street and GeoGebra that we would not have otherwise.”

When it came to the exploration of mean and median, PSTs appreciated the interactive and dynamic nature of GeoGebra as learners, which provides an immediate visual display of mean and median. The PSTs created 43 posts for the first GeoGebra task. Seventeen of those posts were symmetric distributions (see Figure 2a); others were asymmetric (see Figure 2c). Two posts showed dots arrayed in specific shapes: a smiley face (see Figure 2b) and a tree, which were symmetrical. Eight posts did not have mean and median markers on the graph (see Figure 2a), while 35 posts had them on the graph (see Figure 2b and c). PSTs were invited to “like” and comment on others’ posts: One post with all data points on 5 had 13 likes, a symmetrical one with data points at the end had 7 likes, the smiley face had 15 likes, the tree had 10 likes, a non-symmetrical post had 9 likes.

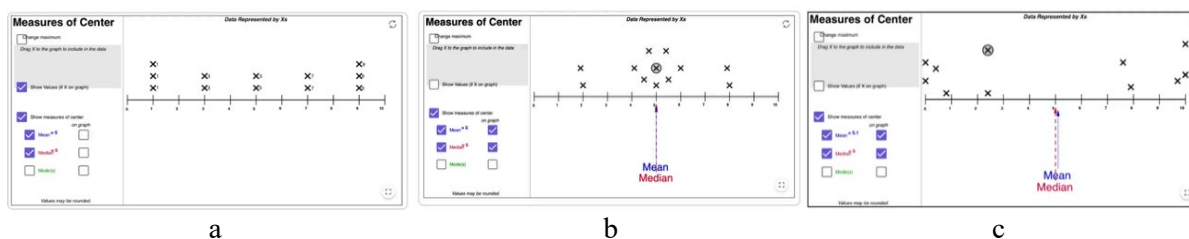


Figure 2. Example posts from the first GeoGebra tasks.

The PSTs created twenty-four posts for the second GeoGebra task. In order to have the median better represent a typical value than the mean, the PSTs often placed data points at either ends ($n=6$, see Figure 3a) or stacked data points on a few data points ($n=11$, see Figure 3b). In five posts, there was no pattern.

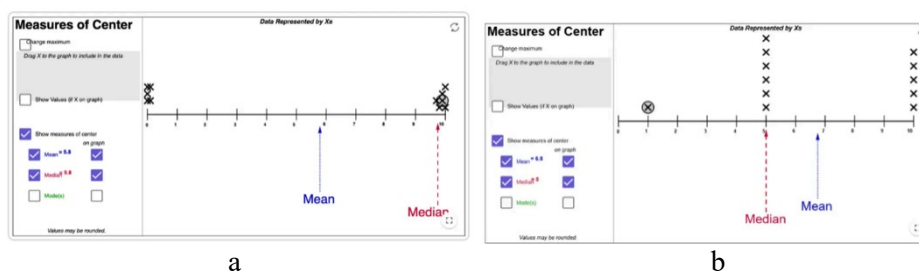


Figure 3. Example posts from the second GeoGebra tasks.

As future teachers, the PSTs were impressed with how different technological tools supported their or in general student active engagement. One PST highlighted the role of technology within the instructional triangle: “Thinking from a future teacher’s standpoint, using technology can be incredibly helpful in creating a connection between students and a lesson. Technology definitely creates a bridge between young learners and lessons.”

The PST’s appreciated how the use of technology supported mathematical communications. They expressed that Padlet was useful for sharing ideas with classmates and accessing different points of view beyond their collaborating tables was beneficial for their learning: “The use of technology in the classroom gave me access to work with my peers in a whole new way. We could easily share our thinking with the Padlet and everyone could see it, sharing our ideas.” The visibility of their thinking provided opportunities for PSTs to form hypotheses about how others created their plots. In one exchange transcribed from the video recording of the lesson, Liz (all names are pseudonyms), a PST with a strong computational background, tried to make sense of a non-symmetric plot posted by Ilene:

Liz: If it were symmetrical, she has an X on 10, so she would have to have an X on 0.

But, instead, she has a 3 and a 2.5...so all her numbers have to add up to something that, when you divide by the number of numbers you get 5. So [I think] she played with the math.

Instructor: Is that how you [Ilene] came up with this? You did the computations?

Ilene: No, I was just playing around with it!

Having to consider other approaches that differ from one’s own is an important step in Liz’s development as a future teacher; and this episode shows that the instructional element offered her an opportunity to build this aspect of her mathematical knowledge for teaching. PSTs also noticed how the use of technologies personalized the learning; for example, Tyra wrote:

My top takeaway from this activity was seeing how powerful technology can be in making learning more meaningful and engaging. Tools like Dollar Street, GeoGebra, and Padlet helped me understand complex topics in a clearer and more personal way. It showed me that, when used the right way, technology can support deeper thinking and help students connect with the content in ways that traditional methods might not.

Looking across the PSTs “noticings” in Table 1, we note the implicit presence of the double-layered instructional triangles shown in Figure 1. This sample of data illustrates how each student noticing includes a nexus of at least two commonplaces: mathematical content, teacher, students, environments.

IMPLICATIONS AND LIMITATIONS

This study opens up for examination the potential of modeling equitable teaching practices in statistics in a teacher education course. The findings affirm the calls by the National Council of Teachers of Mathematics (2024) and other organizations to embed data science and statistical literacy more deeply within K-12 curricula. By addressing persistent gaps identified in elementary teacher preparation programs—where statistics often remains under-emphasized (Sutherland et al., 2024)—this work demonstrates how integrating authentic contexts, dynamic technologies, and platforms for mathematical communication can enhance both PSTs’ conceptual understanding and their pedagogical awareness.

This study aimed to remedy Groth and Bergner's (2006) assertion that PSTs frequently struggle with basic statistical concepts. By leveraging tools such as GeoGebra to shift the focus from procedural calculation to conceptual understanding, and by incorporating globally relevant contexts like Dollar Street, the lesson created space for PSTs to grapple with core statistical ideas in more meaningful ways. Relevance cuts both ways, though. In some cases, PSTs found that the context obfuscated the mathematical ideas or became a distraction. “Honestly, I didn't think the Dollar Street made sense with the lesson. Maybe I was confused but I don't think the connection was established enough between the income averages from the various countries and then the GeoGebra distribution activity.” The abject poverty in Dollar Street, and the implied inequities shown so vividly in the site, may be too overpowering for some in a mathematics lesson.

One challenge revealed in this lesson was the use of technology itself. Most PSTs were able to use different technologies readily, but some struggled. A handful did not know how to take a screen shot of their dot plots to share on the Padlet. A few were not able to get onto the internet. These were challenges we did not expect; the lesson was planned with the assumption that PSTs are digital natives and pick up technology applications quickly and effortlessly. An important takeaway from this lesson is not to make such assumptions.

An important limitation that bears mentioning here is the fact that this study is based on a single lesson. Although we are confident that the findings would be replicated in another delivery of the same lesson, we are mindful that nonetheless very limited claims can be made on the basis of a single lesson. A key implication of this work is the value of teacher modeling, as emphasized by Graham (2020) and Acquah et al. (2020), in making equity-focused instructional strategies visible and discussable within teacher preparation. The lesson design not only modeled equitable practices but also provided structured opportunities for PSTs to notice, reflect on, and critically engage with these practices—helping them bridge their experiences as learners with their evolving identities as future teachers.

CONCLUSION

To meet the goals articulated by NCTM (2024) and others, teacher education courses must include purposeful experiences that foreground technology as a tool for equity, along with engagement. Such practices can help future teachers build the capacity to create inclusive learning environments where all students have meaningful opportunities to develop as statistically literate actors prepared to navigate an increasingly data-driven world.

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