Building Teachers’ Capacity for Data-Rich Instruction: Impact from a Professional Learning Course

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This paper reports survey findings from a broader study about the impact of a data fluency professional learning (PL) course on teacher and student outcomes. These self-reported findings demonstrate evidence of promise for the efficacy of the PL model, which was intended to build teachers’ content and pedagogical content knowledge (PCK) for data fluency through engagement in data-rich STEM investigations, analysis of classroom narratives called teaching cases, and communities of practice where teachers were supported to plan and implement data lessons. The results from pre- and post-surveys given to nine math and science teachers in grades 6–9 show that the PL improved teachers’ data content knowledge and PCK, students’ opportunity to learn with data, and student outcomes. A next stage of analysis will combine these results with other study data to develop case studies that describe the mechanisms behind these shifts. The study contributes to data science education by building new knowledge about features of scalable PL that effectively supports teachers’ knowledge, skills, and classroom practice. Future research should aim to expand teacher participation, diversify subject areas, and examine the impact on student learning with data from student assessments and interviews, to fully evaluate the model's impact.

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Subject/Problem

The importance of K-12 data science education has been called out widely in the last decade. The report *A Framework for K–12 Science Education* (National Research Council, 2012) pointed out the importance of mathematics and data analysis in science education. Next Generation Science Standards (NGSS Lead States, 2013) and The Common Core State Standards for Mathematics (National Governors Association Center for Best Practices & Council of Chief State School Officers, 2010) have also recognized the importance of developing students' data fluency – the ability to actively make sense of and use data with confidence. However, many educators are underprepared to implement these standards (Banilower et al., 2018; Lovett & Lee, 2018). Additionally, the National Academy of Sciences, Engineering, and Medicine (2023) has identified the need for high quality professional learning (PL) in the area of data fluency.

Our project[1] aims to address this need by developing and studying the efficacy of a model of PL to enhance teachers' ability to support their students' data fluency. Our research addresses the following questions: 1) What impact does the PL have on teachers' data content knowledge and pedagogical content knowledge (PCK), sense of confidence in planning and teaching data-rich lessons, and attitudes and beliefs related to data-rich STEM instruction?; and 2) In what ways, if any, did the PL affect teachers' classroom instruction?

Design or Procedure

This paper reports findings from a survey of nine math and science teachers of students in grades 6–9 who participated in a pilot study of a data fluency PL course from Summer 2023 to Spring 2024. The study included teachers from multiple school districts, who worked with students from low-income families and historically underrepresented communities.

About the PL. The data fluency PL was designed to mirror the Making Sense of Science PL Model, which has a proven track record of improving teacher and student science learning (Heller et al., 2017; Heller et al., 2012). This model includes features of high quality PL such as content focus, active learning, coherence, sustained duration, and collective participation (Desimone & Garett, 2015) and the use of a technology tool, Common Online Data Analysis Platform (CODAP, 2024). It also includes coaching and communities of practice to address teachers' concerns and building subject-specific data instructional practices (Hill & Papay, 2022). The PL model supports teachers' content knowledge through engagement in STEM Investigations, refinement of PCK through the analysis of narratives called Teaching Cases, and the transition to classroom practice through Classroom Connection and Communities of Practice. This current project augments the tested PL model to specifically address the needs of teachers in the area of data fluency. Augmentations included the use of technology to engage

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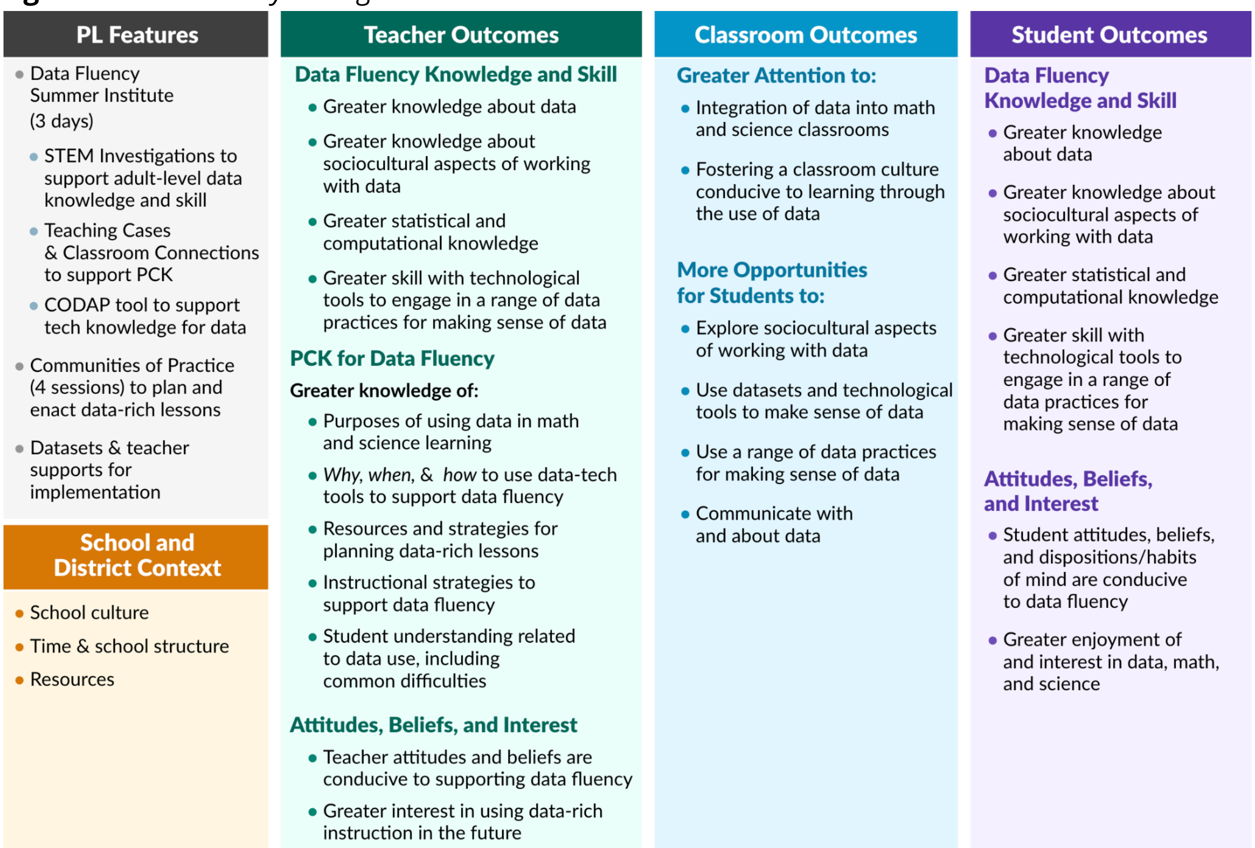
[1] The full project name is *Boosting Data Science Teaching and Learning in STEM*. This material is based upon work supported by the National Science Foundation under Grant No. 2101049. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Science Foundation.

teachers in sensemaking with data; support for teachers to learn more about data and how the data relates to their STEM instruction; and help with identifying datasets and other classroom resources (see "PL Features" in Figure 1).

About the Survey and Analysis. We created a logic model (Figure 1) to serve as the theoretical framework for this study. Surveys were constructed in relation to the logic model. These 60-minute surveys were administered before the PL and at the end of the study. The surveys asked participants questions about classroom resources; beliefs about students, data, and technology; teachers' data fluency knowledge; and confidence in planning and enacting data-rich instruction. We conducted a descriptive analysis of all Likert scale items and coded open-ended items to look for themes and patterns. The full dataset included 13 responses, but we removed four responses due to study attrition.

Figure 1. *Data Fluency PL Logic Model*

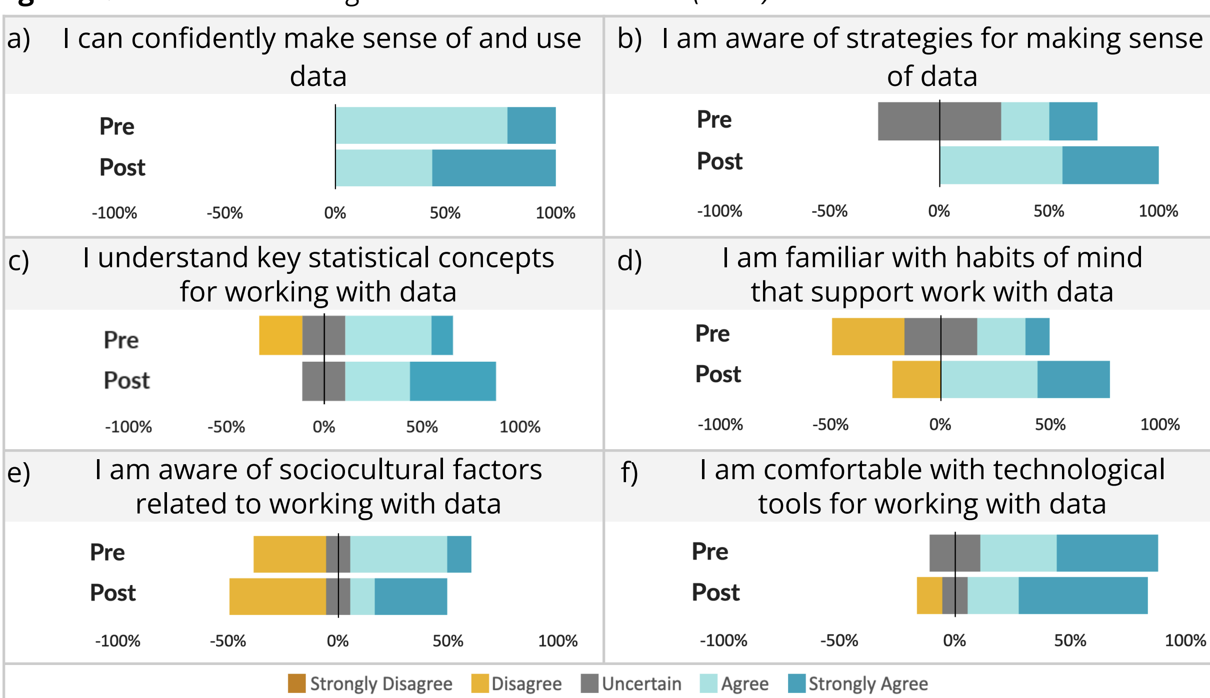


Teacher Characteristics. Among the nine study teachers, seven were science teachers, one was a math teacher, and one was a generalist teaching multiple subjects. Three teachers participated in prior professional learning on engaging students with data in math or science, while the others did not. The study teachers self-selected into the study and were early adopters of technology who had unusually high levels of teaching experience, data-teaching experience, and buy-in. They had an average of 17 years as educators (SD = 6.3), with 67% reporting that they regularly engaged students with data in their Math or Science classes. Teachers who joined the pilot already believed in the value of using data and technological tools to teach STEM content, and held productive pedagogical orientations for data-rich instruction. In the pre survey, all study teachers (100%) said they believe that it is valuable for students to use technological tools to make sense of data, and that data is an effective way to teach math or science content. Most teachers agreed that data is effective for teaching students with varied ability levels (89%) and felt that lessons that use data are more engaging than other types of lessons (78%). They also held constructivist and student-centered pedagogies related to data. Most or all teachers felt that it is important for students to have the freedom to pursue questions of interest in their data learning (100%); take responsibility for their own data learning (89%); and feel comfortable not knowing the answer, taking risks, and engaging in productive struggle while using data (89%).

Analysis and Findings

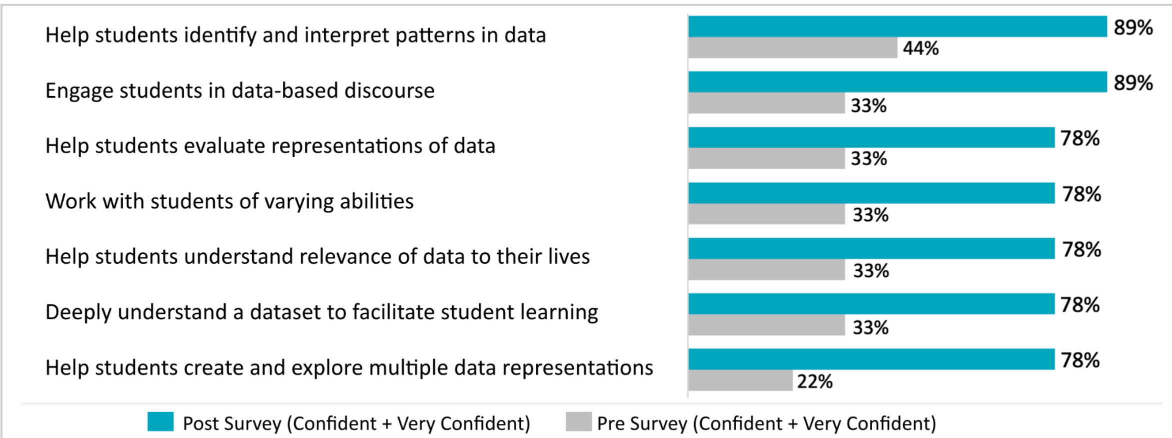
Teachers' *own* data fluency knowledge and skill for making sense of data increased after the PL. At the beginning of the study, all teachers *agreed* or *strongly agreed* that they could confidently make sense of data. However, they expressed even stronger agreement with this sentiment after the PL (Figure 2a). In particular, teachers became more aware of strategies for making sense of data (Figure 2b), had a stronger understanding of key statistical concepts (Figure 2c), and became more aware of productive habits of mind (Figure 2d). With regard to teachers' awareness of sociocultural factors related to data (e.g., ethical considerations) and their ability to use technological tools for making sense of data, some teachers grew *more* confident while others felt *less* confident (Figure 2e and 2f). The introduction of new ideas and tools in the PL may have caused some teachers to realize that they had more to learn about sociocultural factors and technology.

Figure 2. *Teachers' Knowledge and Skill Related to Data (n = 9)*



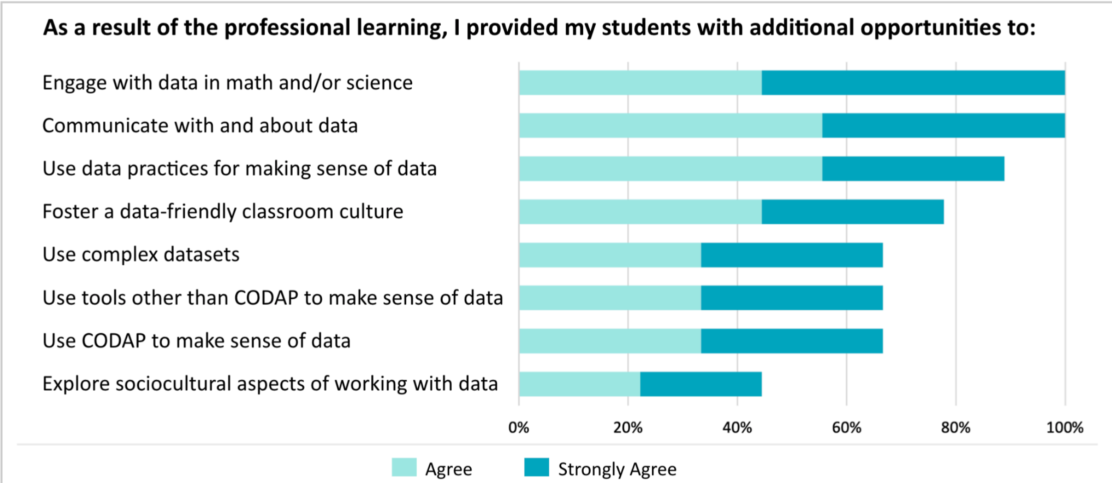
Teachers' confidence in planning and enacting data-rich instruction increased after the PL, signaling growth in their PCK. Compared with responses at pre, more teachers indicated that they felt confident or very confident doing the instructional activities shown in Figure 3. At pre, 22% of teachers felt confident or very confident in helping students create and explore multiple representations. This figure increased to 78% at post. PL support for using technology to engage students with datasets may have contributed to this change.

Figure 3. *Teachers' Confidence in Planning and Enacting Data-Rich Instruction (n = 9)*



As a result of the PL, teachers provided their students with more opportunities to engage with data in their STEM learning. All teachers agreed that, as a result of the PL, they provided their students with more opportunities to engage with data in their math or science classes (Figure 4). Most teachers reported providing more opportunities for communicating with data and using data practices as well as fostering a classroom culture that is supportive of the use of data in STEM learning. Fewer than half of the teachers gave their students more opportunities to explore sociocultural aspects of working with data. In addition to shifting their practice during the study year, all nine teachers shared that they would be fairly likely (11%) or very likely (89%) to use data in their math or science instruction in future school years.

Figure 4. *PL Impact on Teachers Providing Students with Additional Data Opportunities (n = 9)*



Student impact. Teachers also shared the impact their participation in the PL had on their students through open-ended responses:

> *"I definitely was able to do a better job explaining some habits of mind and data analysis tools. My students were more prepared and more successful in engaging with data lessons this year."*

> *"They became more sensible and no longer afraid of too many units or figures in front of them. They are more mindful in making decision and very rational in providing explanation too.*

> *"It made a great impact because I was able to see how good my students [are] in interpreting data and how they can apply their learning into a different situation."*

In summary, these survey findings demonstrate evidence of promise for the efficacy of the PL model. According to these self-reported data, the PL improved teachers' data content knowledge and PCK, students' opportunity to learn with data, and student outcomes. Next, our team will combine these results with other study data to develop case studies that describe the mechanisms behind the shifts in teacher knowledge, instruction, and student learning. These data include teacher interviews, PCK assessments, classroom observations, and student surveys.

The claims that can be made from this study are limited, due to the small size and skewed population. Our study teachers were highly experienced and already believed in the value of data-rich instruction. Teachers who don't share this high level of belief in the utility of using data in STEM instruction may see less benefit from the PL. On the other hand, we might see an even greater impact of the PL on teachers with less prior knowledge and experience. Future work should examine the efficacy of this model for a broader range of teachers, including those with less experience.

Directions for Future Research

The current study focused on science and math teachers. To provide even more students with data-rich learning experiences, future work may help the field understand how PL can support the integration of data into other STEM disciplines, such as computer science and engineering. In addition, the current study's measures of student impact were limited to teachers' self-report and student surveys. Future work can provide a more comprehensive understanding of the impact on students by including data from student assessments and interviews that capture students' data knowledge and skill, sense of STEM identity, and career interests.

Contributions & General Interest

In an era where data science is becoming increasingly vital, fostering data fluency among middle school teachers and students is crucial for developing a more diverse and competitive STEM workforce. Students do not get robust, high-quality opportunities to learn about and make sense of data outside of specialized Data Science or Statistics courses. By supporting teachers to enact data-rich instruction in middle school STEM classrooms, this project helps prepare a more diverse range of students to use data in their daily lives and future careers. This paper contributes to the members of Strand 8, the members of NARST, and the education community at large by building new knowledge about features of scalable PL that effectively supports teachers' knowledge, skills, and classroom practice.

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