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CHICAGO TEACHERS PARTNER WITH LOYOLA UNIVERSITY TO BUILD A MATH AND SCIENCE LEARNING COMMUNITY

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Policymakers and the public are increasingly asking educators to approach instruction from a STEM perspective, integrating science, technology, engineering, and mathematics to prepare students for future careers. At the same time, administrators are directing teachers to make learning more communal and student-driven, emulating the workforce students will likely enter.

Often there is no specific training or support for the teachers who lead these STEM-oriented, collaborative classrooms. A 2013 report issued by the Chicago STEM Education Consortium noted that one fundamental challenge is the absence of a clear and common definition of STEM education (C-STEMEC, 2013).

Since 2003, the Loyola University Center for Science and Math Education has engaged in professional learning with thousands of teachers in Chicago-area schools, facilitating the development and implementation of high-quality instruction that enhances scientific and mathematical literacy. Our goal is to build a cohort of K-8 teachers who can engage their students as mathematical and scientific thinkers.

Two questions drove our work:

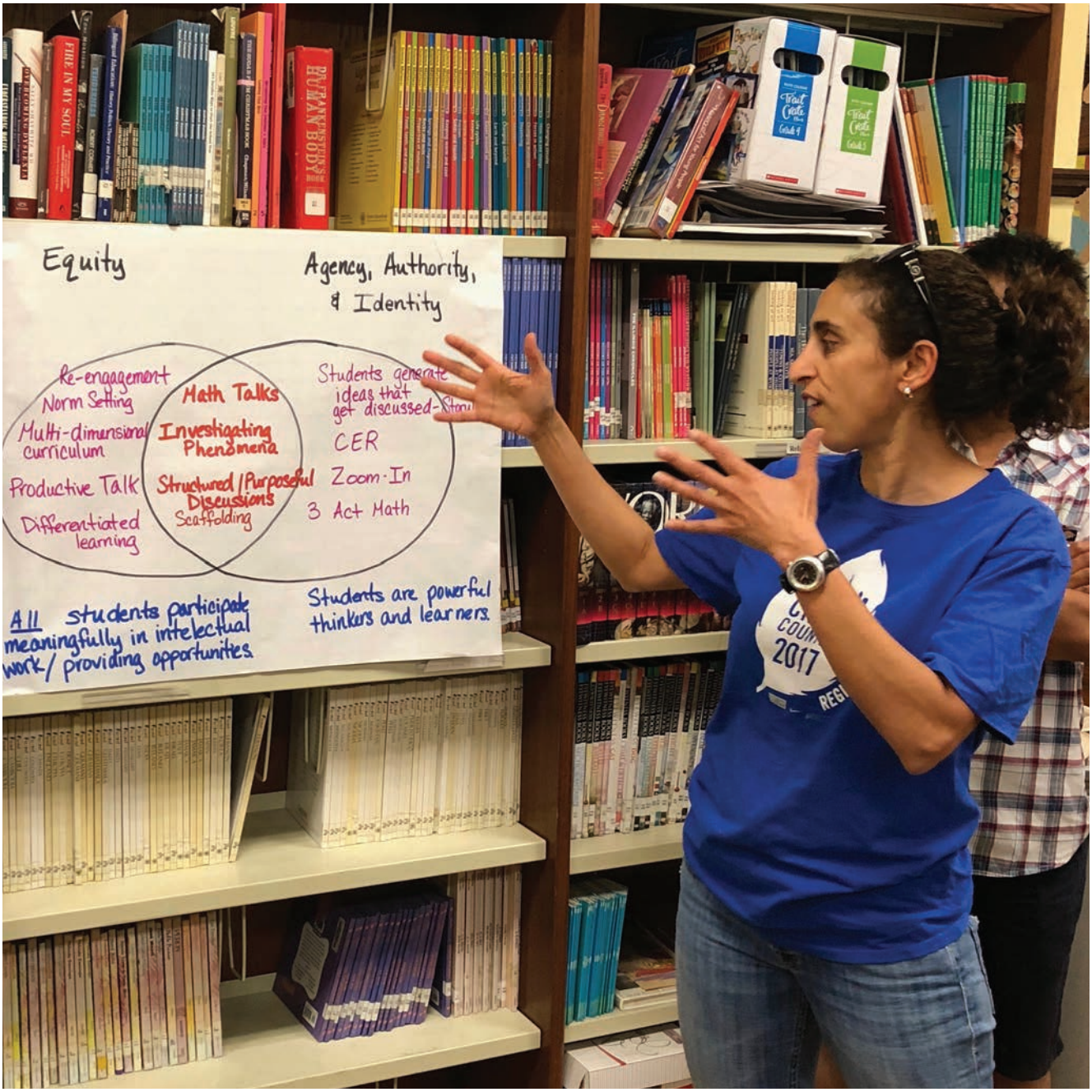
1. How do we get teachers to collaborate around STEM education in a meaningful way?
2. How do we create a common understanding of what science and math integration looks like in the classroom?

An Illinois State Board of Education Math and Science Partnership Program grant allowed us to explore these questions through our Practices in Mathematics and Science: Connections and Collaboration project.

CONTEXT

Both the Next Generation Science Standards and Common Core State Standards for Mathematics outline a set of practices aimed at engaging students in essential processes of science and mathematics. Predictably, there are many areas of overlap. The intersection of these standards and the many shared practices of scientists and mathematicians inspired the Connections project. For example, both scientists and mathematicians ask questions, make sense of problems, analyze data, and communicate their findings.

Over 16 months, a learning community comprising K-8 teachers from Chicago Public Schools convened to develop an approach to making meaningful connections between these disciplines. The format followed the recommendations in the Standards for



Ezeh Judeh, science teacher at James Shields Middle School, presents her school's plan for math and science integration to teachers and administration during the 2018 summer institute at Nathan S. Davis Elementary School in Chicago, Illinois.

Professional Learning for a transparent and authentic professional learning community (Learning Forward, 2011).

Chicago Public Schools has 479 elementary schools, most of them serving grades K-8 and nearly 240,000 mostly low-income students. The project centered on one geographic subdistrict of 21 schools serving K-8 students on the west side of Chicago because district records indicated that teachers in this area had participated in less professional development on the science and math standards than teachers in the rest of the district.

The project team recruited 12 principals to support the project and designate school teams of math and science teachers to participate. A total of 32 teachers participated: two middle grades teachers and two K-5 teachers from each of eight schools.

Participants engaged in 224 hours of professional development, divided among evening sessions, Saturday follow-up sessions, and two 80-hour intensive summer institutes. Throughout the experience, teachers participated in cross-school, cross-grade-level, and cross-discipline

collaboration.

Early in the project, our goal was to increase understanding of Next Generation Science Standards and Common Core State Standards for Mathematics and the relationship between math and science, as well as to develop and refine strategies for connecting the two disciplines. Our goal later in the project was to use formative assessment strategies to drive integrated instruction and build teachers' understanding of how students learn about math and science.

SUMMER INSTITUTE BLOCK SCHEDULE, YEAR 1

BLOCK (3.5 hours)	K-5 teachers	6-8 math teachers	6-8 science teachers
A BLOCK	Math	Math	Science
B BLOCK	Science	Math	Science
C BLOCK	Math/science connections	Math/science connections	Math/science connections

THE FIRST INSTITUTE: BUILDING THE FOUNDATIONS

During the first summer institute, we focused on building the community and establishing math and science foundations. From the outset, we knew that the key to sustainable integration of math and science in these schools was to form a cohort of teachers motivated to collaborate beyond the scope of the project. We also knew that, before we could begin connecting math and science, we needed to ensure teachers had a strong understanding of each discipline separately, especially because the teachers had differing amounts and areas of expertise.

To meet both the community-building and foundation goals, we organized daily sessions into blocks as outlined in the table above.

During A block, K-8 math teachers met together while grades 6-8 science teachers met separately. Similarly, during B block, K-8 science teachers met together while grades 6-8 math teachers met separately. During C block, all teachers came together to experience connections between math and science.

For example, participants engaged in an activity where they attempted to model a total solar eclipse by using ratios and proportional thinking. From this activity, they learned about the science of an eclipse, reviewing the concept of the orbit of the Earth and its moon. In another C block activity, teachers modeled animal adaptations while graphing populations over time, integrating math and science at the middle school level.

This structure allowed us to simultaneously work on teachers' content knowledge while introducing them to the power of connecting math and science. It also ensured that all 32 teachers engaged with each member of the learning community.

Within the larger groups, teachers worked in strategic, fluid subgroups, which were assigned based on the activity's purpose. To challenge each other's thinking about math and science practices, teachers worked in mixed grade levels and schools. If the goal was school leadership, they worked with teachers from their own schools.

FOLLOW-UP DURING THE SCHOOL YEAR

Follow-up sessions maintained support for implementation of professional learning during the academic year. During the 2016-17 and 2017-18 school years, participants attended evening and Saturday sessions and also took part in two book studies and a series of online discussion boards and journaling activities, for a total of 64 hours over the academic year.

During evening sessions, participants reflected on implementation, shared strategies to attend to equity, and developed leadership. Saturday sessions were spent engaging with math and science connections and planning for classroom implementation of the strategies they had experienced as learners.

We developed a planning document to guide teachers to explicitly articulate connections between math and science practices. This document evolved over time to include formative assessment planning and strategies for attending to equity. Teachers also used case studies of teacher leadership in math and science to delve into their role as math and science leaders at their schools (Miller, Moon, & Elko, 2000).

To encourage continued learning between sessions, we provided additional resources through Google Classroom, including professional development guides, slide sets for teacher-led professional development, school math and science vision planning documents, and agenda and notes templates for teacher collaboration.

THE SECOND INSTITUTE: GROUP COLLABORATION

At the second summer institute, we structured the institute differently than the previous summer. Because participants now had a foundation of knowledge and many had strong relationships, we brought them together to experience math, science, and integrated activities.

This grouping allowed participants to be immersed in all content areas and experience interpersonal and intellectual connections that may not have emerged in smaller, more separate groups. For example, in a K-8 school, one might assume that middle school teachers would self-identify as content-area leaders. We found this was not always the case and that the K-5 teachers were some of the most vocal contributors during these open-ended learning tasks.

We engaged teachers as learners in

many novel experiences. These were the same kinds of open-ended tasks we encouraged them to use in their classrooms. As one example, teachers engaged with the Triangle Game (Sally & Sally, 2003, pp. 26-27).

In this game, the numbers one through six can be placed so that there is a number on each vertex and a number on the midpoint of each side. The goal is to place the numbers such that all numbers on any given side sum to the same total. After finding one solution, we encouraged teachers to think about the number of possible solutions and what constitutes a unique answer.

We continually modeled strategies that supported equitable participation, ensuring every participant had a role and the opportunity to contribute. In this example, all participants had an entry point, yet they could develop more advanced mathematical thinking by examining the patterns that arise in this problem. This experience created an environment of mutual respect and collaboration as teachers worked together to understand various solution strategies.

We increasingly asked teachers to share both their work and their students' work with the learning community. This gradual approach to making practice public fostered a high level of trust among participants. In addition to sharing implementation attempts at the start of each session, teachers completed quarterly journal entries in Google Classroom to share ongoing reflections on math and science integration.

This work led to a culminating project in which teachers collaborated with colleagues to develop lesson and unit plans for cross-disciplinary instruction. Teachers also worked toward creating a concrete plan for sustaining school-based math and science collaboration.

ROLE OF ADMINISTRATORS

We included school administrators at key points, including at the beginning of the project, to aid in school-based collaboration and cultivate advocacy for math and science integration. Principals attended one update session midway through the project to discuss math and science collaboration at their schools, and they were also invited to join teachers for a sharing and planning session at the end of both summer institutes.

To facilitate collaboration between teachers and principals, we developed a tool that helps teachers and administrators set schoolwide goals and action plans around math and science and gives them a structure to refer to during future planning sessions.

COLLECTIVE RESPONSIBILITY

The spirit of collective responsibility among all parties went beyond planning and sharing to actually shaping the learning in the project, including a refocusing of the major goals. Although we always knew subject-specific practices would play an important role in the project, we initially assumed teachers would focus on the content connections between math and science.

However, it proved challenging to create learning opportunities that met grade-level standards from both Next Generation Science Standards and Common Core State Standards for Mathematics. For example, an activity that worked toward 5th-grade science goals might only include opportunities to engage students in 3rd-grade math goals.

As a group, we concluded that when teaching students to think like mathematicians and scientists, facilitating connections between math and science processes is more natural and realistic than attempting to integrate math and science content. Facilitators openly acknowledged this change in their thinking and adjusted their plans accordingly, showing they were active members of the learning community.

RESULTS AND IMPACT

We surveyed teachers at three different times to assess the project's impact. Participants rated items indicating their level of understanding of the practices of the math and science standards, their use of instructional strategies aligned with the standards, and engagement in leadership-related behaviors at their schools. The survey was administered at a kickoff session in June 2017, before the first summer institute, and in August 2018 on the final day of the second summer institute.

Analysis of survey results with paired samples tests (N=22) indicated several statistically significant findings. Survey results indicated that both math and science teachers' confidence in their ability to implement Next Generation Science Standards and Common Core State Standards for Mathematics made statistically significant improvement over the course of the project.

On a five-point Likert scale, their post-program responses moved from agree [M=2.1] toward strongly agree [M=2.5] for Common Core State Standards for Mathematics and from disagree [M=1.6] towards strongly agree [M=2.4] for Next Generation Science Standards [both, $p<0.01$].

Additionally, teachers reported a statistically significant increase [$p<0.01$] in knowledge of Next Generation Science Standards and Common Core State Standards for Mathematics practices and ability to make connections between the two content areas, although the increase for Next Generation Science Standards came largely from K-5 rather than 6-8 teachers.

In addition to the survey, teachers demonstrated increased knowledge of the practices through their ability to engage in more nuanced conversations about which practices are important to highlight in different classroom tasks, which we observed during our professional learning sessions.

Also, the K-5 math and science teachers reported a gradual and significant increase [$p<0.05$] in the frequency of engagement in leadership activities at their schools, such as

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planning and facilitating school-based professional learning on the math and science standards at the start of the 2018-19 school year.

At the end of the project, many schools indicated to facilitators that they planned to continue teacher collaboration on STEM practices, and we will continue to track teachers' knowledge and growth. At the start of the 2018-19 school year, district administrators asked us to continue the project. They elected to use their own funds to bring teachers together for four additional evening sessions. This continued work will be instrumental in ensuring the sustainability of the project goals.

WHAT WE LEARNED

We believe that three major design features were key to the development of the Connections project learning community.

Authentic and diverse collaboration. Teacher participants were most engaged when they saw direct implications for classroom instruction through authentic, challenging learning activities, such as the eclipse simulation described above. The diversity of participants' backgrounds and roles also contributed to a high level of collaboration and discourse, building participants' confidence and relationships with each other.

Trust through mutual accountability. The cohort of 32 teachers, along with the facilitators, knew from early in the project that they would hold each other accountable for learning. The book studies required teachers to respond to each other's feedback through the online platform. Later, the structure of the open-ended learning tasks required participants to ask questions and share ideas in an open forum.

Collective responsibility. Because teachers would see each other again in the context of their schools, there was a sense of future accountability to bring the learning back to their classrooms. Our emphasis on gradually developing leadership skills further imparted the expectation that participants would become advocates for math and science, making sustainable collaboration more likely.

This approach may have worked partially because this project was unusually intense: 224 professional development hours in 16 months. Developing teacher leaders is a complex process that was made possible in this project by the considerable time commitment and support from the learning community.

Meaningful and sustained teacher collaboration is an essential piece of realizing a shared vision for STEM education. Although specific instructional goals around math and science integration will continue to change, active professional learning communities engaging in an iterative process of implementation and reflection will directly impact the success of reaching these goals.

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