



Research + Practice Partnerships:

Interactive STEM: Early Mathematics Learning in Technology Rich Classrooms

This is a case study of a Research + Practice Partnership (RPP) located in Maine, between the Education Development Center (EDC), the Auburn School Department (ASD), and math education faculty at the University of Maine at Farmington and the University of Southern Maine. This case study provides a detailed account of how this Adaptation Site of the Research + Practice Collaboratory (RPC) has organized their partnership and their work. It documents how researchers and practitioners come to negotiate this work and provides examples of the structures, tools, and routines that have emerged that the partners use to facilitate this process. Critical moments in the development of the partnership are highlighted here, as are the multiple benefits of the work to a range of stakeholders and audiences.

This case focuses on the design and functioning of the partnership, with attention to several focal points of special interest as outlined in the Sections below.

Section I. **An overview of the partnership and a summary of activities.**

Section II. **The conception, initiation, enactment, and evolution of the research-practice partnership**, focusing on the roles that researchers and practitioners played in decision-making and defining the work.

Section III. **The area of common interest— its designation and evolution**, describing how the problem or inquiry was framed, has evolved, and been deemed important.

Section IV. **The relationships and interactions between researchers and practitioners**, portraying the roles and dynamics between the individuals involved.

Section V. **The multiple benefits of the partnership**, considering the immediate and long-term outcomes of the work of the RPP.

Section VI. **This case as illuminative of design-based Research + Practice Partnerships**, reflecting on the work in the larger context of the Collaboratory effort.

The Research + Practice Collaboratory

The Research + Practice Collaboratory (<http://researchandpractice.org>) aims to explore and demonstrate ways that research and practice, and researchers and practitioners, can interact in a variety of non-traditional ways to support educational improvement. The original vision communicated to NSF: “The challenge is not how to create better or more devices or artifacts that translate research to practice but rather how to create richer opportunities for cultural exchanges between communities of research and practice” (Coburn & Stein, 2010). The Collaboratory created the concept of “adaptation sites,” later called “local labs,” to identify local STEM improvement projects where researchers and practitioners in a range of educational settings would partner for the purpose of creating such contexts for cultural exchanges leading to new knowledge and improved practices.

Inverness Research conducted multi-year case studies of the research-practice partnerships deemed “local labs” for the Collaboratory. The cases aim to portray details of the leadership, design, and implementation of the partnerships, and to offer reflections on key features that shaped the interactions and work of the joined communities of research and practice.

I: OVERVIEW

The Education Development Center formed a partnership with the Auburn School Department in Maine to create and support networks and relationships that connect pre-K to 2nd grade teachers, administrators, and district personnel with researchers (from both EDC and local institutions of higher education) to bridge research and practice. They work collaboratively on persistent problems of practice related to early math learning, low mathematics achievement in the early grades, and the use of technology (specifically, iPads). Over the past three years, they have developed shared visions of practice and interventions for addressing key areas across the broader early math learning/technology umbrella (student understanding of number sense, for example). They have also focused on documenting, through videos and briefs, how the collaborative relationship is developed and specific intervention models that help address these persistent problems of practice.

The Partners

Education Development Center: The R+P Collaboratory Team at EDC includes Dr. Pamela Buffington, Catherine McCulloch, Josephine Louie, Amy Busey, Marian Pasquale, Peter Tierney-Fife, and Jenn Stiles. Buffington leads the team; McCulloch, the Project Director, focuses on developing strategies to bridge the research and practice divide. Louie's role as a research scientist focuses on the overall conjectures within the work of this particular RPP and helps conceptualize the research questions, among other duties. Busey, Pasquale, and Tierney-Fife are researchers; Stiles is the Project Coordinator. Dr. Ashley Lewis Presser and Barbara Berns from EDC, and Andee Rubin from TERC, serve as advisors.

Auburn School Department: The partnership has involved more than 50 teachers, administrators, and district leaders, with a group of about 15 core participants. Key leaders from the ASD include Katy Grondin, Superintendent; Michelle McClellan, Assistant Superintendent; Carol Miller, Technology Integration Specialist; Shelly Mogul, Curriculum Director; Mike Davis, Principal at Walton Elementary School; Celeste Beaudet, Principal at Fairview Elementary School; Sue Dorris, Principal at East Auburn Elementary School; Vicki Gaylord, Principal at Park Avenue Elementary School; Laura Shaw, Principal at Washburn Elementary School; Kim Taylor, Principal at Sherwood Heights Elementary School; Amber Eliason, Elementary Math Coach; and Mike Muir (who was Multiple Pathways Director but left the district and is now Learning Through Technology Policy Director at the Maine Department of Education). The participants are pre-K–2nd grade teachers and principals from three of the highest-needs elementary schools in the district as well as school district administrators. In 2015-2016, three schools were added to the partnership, including one that has the highest percentage of English language learners in the district.

The partnership between EDC and the ASD came about because Pam Buffington from EDC knew that ASD was implementing iPads in grades K-3, and they were looking to improve their mathematics achievement scores. She worked in the Auburn School Department in the past and she knows the district and the people in it very well. She also collaborated with the ASD previously on a technology initiative.

The University of Maine at Farmington and the University of Southern Maine: Two mathematics education faculty also participated in the adaptation site work. They were recruited by EDC to “build bridges between practitioners in ASD and researchers at local higher education institutions to sustain research-practice relationships after the project ends.” Dr. Shannon Larsen is an Assistant Professor of Education at the University of Maine at Farmington. Dr. Larsen teaches elementary math methods, and her role in the project is to provide research articles to support the work, support the professional development, attend group meetings, and observe and assist teachers in the classroom. Dr. Kelly McCormick is an Assistant Professor of Mathematics Education at the University of Southern Maine. Dr. McCormick teaches mathematics content and methods courses for pre-service and in-service teachers. Her professional interests include learning more about the development of children’s mathematical thinking and reasoning, and the preparation of teachers of mathematics. Her role in the project is also to provide research articles to support the work, support the professional development, attend group meetings, and observe and assist teachers in the classroom.

Key Activities of the Site

Key activities fall into several distinct phases, which we will discuss in more detail in Section II. The first was a “launch phase” focused on creating the partnership, building trust between researchers and practitioners, and identifying the persistent problems the collaboration might explore. This phase included EDC approaching the Auburn School Department, creation of a memorandum of understanding that laid out the agreements of the collaboration, recruitment of mathematics education faculty from two nearby universities, and initial meetings with teachers, principals, and district leaders. Throughout this phase, the researchers and practitioners collaboratively identified needs in mathematics learning that they would address through the partnership.

The second phase focused on building the shared language and vision of effective mathematics learning and teaching, particularly with regard to the use of technology in early grades classrooms, through professional development sessions and ongoing meetings. Three schools (including one teacher from each K-2 grade level and the principal) were identified to be the core participants, and a “design team” that included key district and teacher leaders was formed to guide the effort. EDC shared research briefs, literature, videos, and open-source iPad apps in professional development sessions, and efforts were made to tie the research being shared into the district’s mathematics curriculum, Everyday Mathematics.

The next phase of work involved participating classroom teachers testing out strategies with an iPad tool and reflecting on and sharing their experiences. The district created a math coach position and hired one of the participating teachers to fill that slot to provide ongoing support for the project. School-based co-investigation teams were created to gather data on the strategy testing being done by teachers. These teams included one EDC staff person or one of the higher education researchers, the math coach, and the school principal. EDC researchers worked with school district participants to develop hypotheses to investigate in the next phase of work.

The next phase, in the spring of 2015, involved the full investigation of one of their hypotheses: *When students record and review explanations of their thinking when solving mathematical problems, student engagement in mathematics and learning will improve.* (For the full list see Section II.)

At least twice a month, teachers had students use an iPad app to record and review their explanations of mathematical thinking, and teachers completed an online log about how they implemented the strategy, the outcomes they observed, and any adjustments they might make. Monthly meetings among the co-investigation teams allowed teachers to share their experiences and discuss adjustments. These meetings also allowed math education researchers to share new learning resources.

In the summer of 2015, another cohort of three schools joined the project, and through summer professional development and design team meetings the work for the 2015-2016 school year was mapped out. These new schools have engaged in work similar to the cohort 1 schools. The focus for the coming year includes a particular focus on frequency of recording for all students, and explicit focus on strategies for English learners and struggling learners.

II. THE CONCEPTION, INITIATION, ENACTMENT, AND EVOLUTION OF THE RESEARCH + PRACTICE PARTNERSHIP

Pam Buffington had worked in the Auburn School District, both as a staff member and as a collaborator, and therefore was aware of Auburn’s technology initiatives (one-to-one iPads in primary grades) and their interest in capacity building. She had been looking for ways to collaborate with them around primary math and the iPad initiative, and the research-practice collaboration seemed a good fit. The district was looking to jump-start an initiative in mathematics and technology to help address low performance in math in the early grades and had little to no professional development or math coaching to support improvement efforts.

The first phase of the work between EDC, the ASD, and the mathematics faculty was all about building trust and a good working relationship. This six-month period involved many discussions and ongoing collaborations with all the stakeholders to discuss persistent needs in the district, until they all settled on the teaching of mathematics with technology as the collaboration’s area of focus.

Over the course of the following three months, EDC held several professional development sessions. Through shared readings, activities, discussions, and videos, the group worked to engage with research and to develop a shared vision of effective mathematics teaching and learning. EDC continued to meet with teachers and principals from the three schools, and key district leaders, to further develop the partnership and logistics for working arrangements in the coming school year.

The next phase took place in fall 2014, with monthly meetings among the teachers, EDC, and the university faculty to discuss how teachers would implement teaching strategies they had worked on in the summer professional development. Each month, teachers had to try one strategy with an iPad tool as part of a mathematics activity, and then reflect on their experience. The Auburn School Department hired one of the participating teachers to serve as an elementary mathematics coach to support teachers. In addition, “school-based co-investigation teams” were formed—one for each school, consisting of an EDC staff person or one of the university researchers, the math coach, and

the school principal—to collect data as teachers tried new strategies. Classrooms were also observed during this phase.

As Pam Buffington explained, “Through the fall, EDC researchers began to work with Auburn participants to develop hypotheses about what types of classroom strategies with iPad apps could lead to improved number and operations abilities and mathematical practices in early grades. Teachers were asked to develop these hypotheses based on their experiences with strategies they were using in the classroom as well as what they had learned from readings of the research literature. The hypotheses fell into four broad themes:

1. If students record their voices when thinking through mathematics problems, then positive learning outcomes will arise.
2. If students use specific iPad apps, then positive learning outcomes will arise.
3. If teachers set clear learning goals and choose iPad apps to match these goals, then greater student learning will arise.
4. If teachers incorporate real-life problems into mathematics learning activities, then students will demonstrate greater engagement in these activities.”

In the winter and spring of 2015, teachers, researchers, and administrators further refined their hypothesis to test during the rest of the school year: *When students record and review explanations of their thinking when solving mathematical problems, student engagement in mathematics and learning will improve.* Teachers had noted that students seemed to reflect more critically on their own work solving math problems when they used a recording tool. Similar to the earlier phases, teachers tried strategies using an iPad app that asked students to record and review their explanations at least twice a month. Teachers recorded in a log how they implemented the strategy, any outcomes they observed, and what they might do differently to improve outcomes. The monthly meetings among the team continued, where student data and artifacts were examined and plans were made for the next implementations. EDC continued to provide professional learning opportunities for the teachers, at their request. The EDC team described this phase as “30-day iterative Plan-Do-Study-Act cycles in which teachers reflected upon, refined, and re-implemented the group-designed strategy.” Monthly meetings and visits from school-based co-investigation teams continued throughout this phase.

In the summer and fall of 2015, another cohort of three schools was added to the partnership project. Professional development was provided and these schools engaged throughout the 2015-2016 school year in the exploration of student recording and its impact on student engagement and learning with EDC, the two university faculty, and the other cohort of schools. One teacher who participated in a cohort 1 school became a vice principal at a school in a nearby town, and she has taken the research-practice work to her new school and is implementing it there. The 2016-2017 work has focused on documentation and dissemination of the partnership’s work and seeking new sources of funding to sustain and expand the work. (See Epilogue for more details.)

III. THE INQUIRY OF COMMON INTEREST— ITS DESIGNATION AND EVOLUTION

In addition to Pam Buffington’s previous work with the district and her interest in the areas of mathematics and technology, other initiatives in Auburn that influenced the current partnership were K-12 customized learning, and Advantage 2014. The district was an early adopter of Advantage 2014, a technology and learning initiative that placed iPads in all middle school and high school students’ hands. It was also the first district in the state to place iPads in early grades at the elementary schools. Another previous initiative in the district focused on the teaching of literacy at the elementary level, which raised awareness of a need to focus on mathematics as well. The district is also focused on collaborative work that builds district capacity, using shared leadership teams across projects and initiatives.

Early work focused on developing a shared language and vision around what students needed help with. As Pam Buffington explained:

One of the observations I had, but also our team and the math education researchers had, was when we did our initial problem identification there wasn’t a very deep or specific math language around what students struggled with... So they knew the students were struggling with numbers and operations, but they couldn’t talk more specifically about that. We also identified that there wasn’t a shared vision of what good math teaching and learning was in that early level. Nor was there rich math communication going on in the classrooms. We wanted to develop a clearer shared language so they could talk about the problem better... so everyone gained this working language. We also integrated the use of the apps that were math-specific tool, and some tools that could be used to help with the communication aspect. For example, we did some baseline data analysis based on the CPAA assessment they did in the district— literacy and math items. One of the report items was about students’ ability to look at a grouping of objects and know the amount without having to touch or count them— subitizing... When we reported that students up to 3rd grade weren’t able to do that, some of the descriptions of how to intervene included giving kids time to count—and we didn’t understand what that meant. So we provided a research brief about use of technology, but also digging into the learning trajectory of students learning early math. All of a sudden, folks had a more sophisticated way to describe what kids were doing or not doing... They are able to intervene differently... That’s a huge thing.

Key Strategies Used to Develop the Partnership

Two strategies that nurture the partnership are ongoing observations of classrooms and the use of videos as a means to develop shared vision and understanding. Again, as Buffington explained:

I observed early on that maybe they weren’t using the tech in the most powerful ways or they didn’t have a good shared vision of what good practice was from the beginning... It’s hard to say we are going to fix a problem we can’t describe well enough. So we were purposeful about using video, and about opportunities for them to work together. And ‘we’ means math education researchers and practitioners developed that shared understanding. It wasn’t that any one of us was saying, ‘this is the way it should be,’ but instead, we said, ‘Let’s watch the video, what do we notice, what do we know?’ So providing these kinds of opportunities to dig into the research a bit more helped us.

Another key strategy in the development of the partnership was the careful attention to power dynamics and setting up opportunities for teachers, administrators, and researchers alike to be “learners” in the relationship, leveling the playing field. The partnership worked diligently to identify a problem of practice that was important to the teaching community but also had value from a learning standpoint for the researchers involved. As Buffington noted:

We've been really attentive to and purposeful about not setting up power dynamics that would lessen one person's voice in the conversation. One of the things we did early on was to integrate the use of the technology apps, and we had math researchers, principals, all of us doing it together. The teachers have expertise in using the tech for a particular purpose—we all engaged in it together—so that helped create a more level field for engagement....The other thing is the two math education researchers came to this from the perspective of 'I know math but I haven't used these technologies in the classroom'... so they approached it with a learner and doer mind set... All of that really helped early on to create the relationships.

One of the math education faculty, Kelly McCormick, echoed Buffington's sentiments:

I think from the beginning, one thing is that we are working together. It's not a top-down type of project.

The math coach, Amber Eliason, indicated that as the partnership evolved over time, the researchers were guiding everyone through the process, but it was the teachers who ultimately decided on the direction. She also noted how early on, the teachers wanted the researchers to tell them what to do, and the researchers always pushed back:

There were a couple of meetings that were kind of tough because it was definitely working out the research, and a lot of the practitioners just wanted them to tell us what to do. We were like, 'can't you just write the hypothesis?' But they said 'no, we can't, because we're deciding this together.'

Another key strategy has been the pacing of the process, moving slowly enough that the groups had time to deeply explore areas they were interested in, to try things and learn from them, and to head down paths that developed along the way. The partnership was structured so that the work in the fall would allow teachers and researchers to engage in joint exploration, so that by the time spring came it was a joint decision about what would be explored in depth going forward. The team identified strategies to implement, attempted them, gathered data (from video, to classroom observations, to student artifacts, to outcomes and assessment data) and discussed together what worked and what didn't. Their early work around helping students with number sense, along with continued exploration of how best to utilize iPad apps in early mathematics, led them to evolve their hypotheses. Eventually, they focused on the benefits of students recording their problem-solving explanations and reviewing those recordings as a means to develop students' explanation skills and their mathematical understanding. Buffington explained how the work evolved:

What we did in the first few months was to try a strategy they wanted to try... then we continued to revisit the problem and say 'what do we want to drill deeper into?' So the group refined the research questions—we are seeing that students engage more and self-correct when they are using these tools and representations, but using screen-casting tools like Explain Everything... When students are actually recording explanations of their math thinking they have more ownership...From January to now, and continued through the end of the school year, the teachers are trying out these things, capturing student artifacts, bringing those to monthly meetings, and talking about what they are

seeing. As part of that, the teachers have identified the need for curricular opportunities for students to engage. We all agreed that students need richer tasks... so we integrated a component about rich tasks through a presentation by one of the math education researchers... and then the teachers tried some things and refined their strategies... Now we are working on a research brief about strategies to elicit math talk and some models for doing that. We are seeing the teachers gain more and more ownership of how they are investigating what they are trying.

Another strategy is the formation of co-investigation teams in each school. The teams are comprised of the teachers and principal from the school, one or more people from EDC, and one of the mathematics education faculty or Buffington. These school teams also are part of the larger monthly meetings where everyone shares what has been happening in their school and plans how to progress from there. Buffington explained how these teams work:

All year, we work together to observe classrooms and think about what the teacher wants to explore. We go to each classroom at least once each month. Then the principal who is part of the team also does some observations, not formal capturing video, but he or she comes and talks to teachers and gives feedback. We are pretty active. Plus we meet once a month with all the teachers and principals in the three schools, and have a meeting once a month with myself, the two math education researchers, the math coach, and usually another one or two of our EDC team, just to check in across schools... That's been a really important structure to getting more systematic about what they are trying out.

Eliason explained how the dynamic among researchers and practitioners played out in specific classrooms:

The three of us—the classroom teacher, Shannon (the mathematics education researcher), and myself—go around to different groups, and sometimes it will be video and sometimes it will be questioning, and sometimes it will be one of us sharing with the others what a specific student is doing... It was very clear from the get-go that this was a partnership, a co-investigative team... Shannon was always great about letting teachers know how much she valued what they knew about their students, and that leveled the playing field for a lot of teachers. They felt really good about how everybody here has something to offer and together we can do what is best for our kids. So as opposed to somebody coming into my room to watch how I am doing, it is definitely not that. It is more 'we are going to try this stuff together, and we are going to look to see what the kids do with it and whether it seems to be changing how they approach math'...

Another key strategy has been a monthly meeting of a core group to help plan each phase of the work, including a couple of people from EDC, the mathematics education faculty, and the math coach from the district. As one of the math faculty explained:

We meet once a month for dinner and talk about what the teachers were working on and struggling with. Then we'd decide what to collect data on. That's been part of the planning—pulling everything together.

Throughout, EDC has used the conjectures to frame the thinking about the Adaptation Site work, to reflect on the design and implementation of the work, and to reflect on the district and school contexts, the nested aspects of the persistent problems, and the assumptions that are driving their work in the district.

IV. THE RELATIONSHIPS AND INTERACTIONS BETWEEN RESEARCHERS AND PRACTITIONERS

Roles

The partnership began with everyone taking on the stance of their traditional professional roles: teachers and administrators as practitioners; math education faculty as researchers; and EDC in a hybrid role as facilitators of the work as well as researchers. As Buffington said:

EDC plays a hybrid role. We are the broker in the partnership. We are researchers as well because we keep coming back to ‘what are those questions we are going to try to answer and get consensus on among the group?’ We are spending time in that dual role of being a researcher and being a facilitator of the work.

Buffington also described that even within the EDC team, there are different roles:

It’s hard to attend to the equal voices in all of that if you are coming to it as a researcher solely. So even within our team we have different roles—where Jo Louie is very much researcher, and my role is both... I can easily shift back and forth in perspective.

Within the collaboration, Buffington’s hybrid role has been key. She had worked as a practitioner in the district, she brought the research perspective from EDC, and she could bridge the work of the partnership with the larger Research + Practice Collaboratory work.

As the group has worked together, through the strategies outlined in other sections, there has been a shift into more hybrid roles all around, with the mathematics education faculty trying new tools and strategies in their pre-service courses, and the teachers moving into more of a research role along with their implementation role. Because the key questions this partnership focuses on are technology-related, which is not an area of prime expertise among the two mathematics education faculty, it helps create a mutual learning role among the teachers and the mathematics faculty. Mathematics education faculty are learning about new tools and approaches that they, in turn, are bringing into their pre-service courses, just as the teachers are learning about research that informs their practice (more about this in the next section).

One of the mathematics education faculty explained how they have extended the teachers-as-researchers focus into the research analysis:

As we’ve focused more, looking at the themes and coding the data, initially it was us researchers doing the coding. We got into a conversation in January, Kelly, Pam and I—if this is really a collaborative, shouldn’t the teachers be involved as well? So we took video clips we had shared in a conference presentation, played the videos, and asked teachers what they noticed. Then we shared our coding and asked if there was anything missing, and we did add a few things. So this notion of mutual value, we are always coming back to that, and the teachers play such an important role.

Another key hybrid role from the practitioner side is the district math coach, Amber Eliason. She serves as supporter, encourager, and facilitator, helping the process of implementing the strategies in

the classroom. A former teacher, she bridges the teacher and district landscapes well and can help in the core team meetings to facilitate researchers' better understandings of the school and district context. One of the mathematics education researchers, McCormick, described the importance of the math coach's role:

The math coach is really good, and she is great at encouraging teachers. If a teacher wants to try things, she'll co-teach or help out in any way. She is in the schools a lot more than we are. She's been an integral part. Some of the teachers were nervous about working with technology for some content, for some open-ended questions, and she's been a nice safe bridge for them. I think it's been great to have her there this first year.

The math coach, Eliason, said:

I feel like I have definitely been more the practitioner, but a little hybrid in support for the teachers to be able to actually do the work that we are hoping gets done.

V. THE MULTIPLE BENEFITS OF THE PARTNERSHIP

This research-practice partnership has been of value to all who have participated, and the benefits reach beyond the immediate partners.

Benefits to the Teachers and Administrators

The local teacher-practitioners in this partnership have received access to research and a supportive network for understanding that research and applying it to their practice. Teachers have not only found valuable apps to use with their students, they have learned how to do so in ways that promote active learning and dialogue among students. They are also applying these tools and strategies in other subject areas. As Eliason noted:

So this different approach, where it's an app that requires a conversation or interaction with a partner or a teacher... it's nothing that you just play with or zone out doing it. It requires interaction. So that approach to technology, I think, has been big, and not just for math. I have seen it move into other content areas in those classrooms, too, like in language arts, using Explain Everything for writing stories and spelling and recording—things like that.

Buffington shared a comment from one of the participating principals:

One of the principals said it was terrific for teachers to have access to the latest research, and how they have been able to try new strategies based on the research, and in doing so the teachers have become researchers themselves. The principal is observing that shifting sense of the teachers as researchers, and the teachers being able to design, try, implement, adjust instruction, observe what's truly effective, and have conversations about it. That is a huge thing.

One mathematics education faculty member commented on what she sees teachers taking away from this experience:

For teachers, they are learning a lot more about what they are teaching, the math content. They didn't have the building blocks of how the concepts build and why the strategies are important and how they all fit together and what pieces their students aren't getting, so you can see all that deepen. And how important students' talking together about the math concepts can be. They are strong teachers, but they had no view of math in this way...

Mathematics education faculty also see teachers adapting their teaching in new ways, based on their interactions with both the researchers and their colleagues:

It's interesting how the teachers are adapting their teaching with the technology and creating things with partners, and then listening to each other and reflecting on their work. I see teachers using more open and interesting problems that often have more than one way to solve them. It's amazing how much better they are getting at all of this. And a lot of it comes out of the interactions they have with us and with each other. One of the things I've been bringing in is a discourse rubric, and one teacher identified where she is and where she wants to be, and she pushes herself. And some of the other teachers are picking up some of the things she is doing.

Jo Louie, researcher from EDC, described how the deep, rich, authentic work of this collaboration has been so impactful:

The engagement of these teachers in this work has been really strong, and multiple people in the district have been saying this is different from a normal 'people come in and do professional development and leave' type of situation. First of all, it is sustained, ongoing and job embedded—all of that stuff about good professional development. And because we have been working with them to identify their problems and shape any professional learning activities around what they are asking for and what their needs are as they have evolved, there has been this sense that there is a lot more buy-in to the work. So teachers are more excited to try these strategies because they have been there from the beginning to come up with them.

Teachers and administrators see significant value in the work they have been engaged in through the research- practice partnership. They see classrooms differently, and see the processes that have been put in place as something that could be continued, sustained, and carried over to other subject matter. As one administrator noted:

Beyond having access to research and information about how young children learn in math... what that progression is and how to get from one level in the progression to the next, just having a systematic protocol for implementing practice and looking at it and seeing if it's working has been really a nice model. This iterative cycle of getting research-based information, trying it, recording ourselves, talking about it, meeting with others, processing that through, and then going back and doing it again—I think if nothing else that whole process is something we could always continue.

Louie also noted that Mike Muir, the former primary contact in the district (who is now with the state department of education), commented on how much being part of the collaboration had taught him about school change and reform:

He said that he has gained some insight about what really promotes school reform and school change. He said by working with us, it is not about the tools and the technology or a specific research approach, it is about building relationships right from the very beginning—strong relationships that are built on trust and communication and working together on problems and solutions.

Benefits for Students

Collaborators in this research-practice partnership see this paying off not only for teachers, but also in enhanced opportunities for learning for students in participating teachers' classrooms. One of the mathematics education researchers, McCormick, noted that there are now more opportunities for students to do and think about mathematics in these classrooms. And Buffington noted how the energy and activity in the classrooms is quite different now than it was before the project began:

It's really fun and exciting to be in those classrooms now. Before this project started, I observed that the way technology was used in the classroom often was student, iPad, earphones—the tool wasn't integrated into classroom instruction in the same ways. For me and the teachers, the way kids are engaging is very different now...the excitement among students, the amount of math talk—that's huge...

EDC's Louie also talked about how the students, by listening to themselves when using the recording app, are not only engaged but actively correcting their thinking and deepening their understanding:

These kids at that age just love to hear themselves. And as soon as they hear themselves explaining their own solutions to a mathematical problem when they play it back, they are so engaged. And they often times hear their own mistakes and will correct themselves, and they will record it again. So they are becoming more metacognitive, and they are learning so much through this.

In fact, researchers and practitioners noted how the changes in classroom practice that have come about through the application of the iPad recording app have led to more equitable mathematics experiences for students. Buffington shared stories of how students who had previously struggled, or for whom teachers had difficulty finding mechanisms to truly see their mathematical thinking, are now having success:

The growth in student voice and student choice in terms of the tools they are using, and the impact it is having for students who aren't the higher performing ones, has been amazing. We had one student in a class who was selectively mute—he hadn't talked into the beginning of 2nd grade. Now this student is recording his voice and playing it for other students. We've had similar reports and observations of students with autism recording and talking and being very focused. We've observed students who are shy who will record independently or with a partner and show it to the whole class.

Benefits to the Researchers

The mathematics education faculty have also benefitted from their involvement in the project. Both are isolated—the only math education faculty in their departments. The opportunity to work with other researchers as well as the teachers and district personnel has been invaluable. It has not only helped them with their research, it has helped them build expertise in an area (technology) that wasn't their strong suit, and given them new strategies and tools to use in their pre-service courses. As McCormick said:

I am the only math education faculty here. So it's been great—focusing on teaching and learning, specifically on math. Even in our state, you would think we network more, but we don't often. So I got to meet the math educator at Farmington for the first time and now we see each other all the time. This is such a fun research project because the teachers are so involved; they are engaged

more. And it is about technology, which is not my main strength, but Pam [Buffington] does such a great job with that. I had no idea what even was out there in the way of apps in this area.

Both mathematics education faculty have brought elements from the partnerships back to their pre-service courses. Shannon Larsen noted how she has brought both the apps and the strategies for using the apps, as well as the district math coach, into her pre-service course:

The first semester, I had Amber [the math coach] come into my class and she talked to my students about choosing technology and choosing iPad apps, and she gave them rubrics to choose what apps to use. The students started with a learning problem, chose an app, and then used the rubric to evaluate the app. Then we discussed any adjustments they'd make for the app. I have my students use the Explain Everything app to solve and explain a math problem, and then they save their video to a Google drive folder for the class. Their homework was to look at how two other students use Explain Everything—with some questions—to share in class. I really want my students to learn some of the things I am learning in Auburn from those teachers.

And McCormick uses the apps as well as classroom videos of students and teachers working with the apps in her elementary content course. She said:

I am bringing in a lot of examples I am seeing students do—whether it's a video or sharing an example of what teachers and students are doing. For example, we are thinking about examples of equity, student self-assessment, peer-assessment, and changing teacher beliefs about what they believe their students are capable of and the tasks they are assigning. I've been sharing some of the videos with my classes and we talk about that and the value to teaching of having that to look at...

Both noted how much value they find from having the opportunity to regularly be in classrooms, working with teachers and administrators, and staying connected to the realities of K-12 teaching and learning. As Larsen said:

I still love that I have the opportunity to be in schools. This is only my fourth year living in Maine, and one big concern I had when I took this job was not having any connections. I felt so removed from the classroom. Having the opportunity to have connections with teachers and administrators and be in classrooms is so helpful. I can try things out and find out these things still work or I can figure things out. Because I have been in the classroom so much, it gives me validity when I am talking to my students.

The math education faculty members also value the design-based research process. As Larsen noted:

I like this designed-based research practice. I feel more sure about what we are finding and saying because it is a group that is saying it; it is the researchers and the teachers. I feel like it makes the findings more connected to practice and maybe more doable for teachers, because the teachers are engaged in the research. We are not doing it for them.

Benefits for EDC

EDC has benefited from the RPP as well. This particular partnership, with its focus on the classroom, building, and district level, is somewhat unique in the partnership project portfolio within the research, evaluation, and policy unit at EDC. There are also possibilities for taking this model into other projects as well. As Buffington noted:

There are a couple of other opportunities bubbling up around applying this model with some cohort of districts and community people in another STEM area. We'll see going forward in the next few months... It certainly has positioned us to do more of this type of work where we are applying what we know to these different settings... I see that as being a real positive.

EDC has been active in sharing the nature of and the findings from this partnership with the broader field through presentations at numerous conferences, including AERA, and this has been of benefit as well. As Buffington said:

Being able to participate with others at AERA positions EDC as one of the players in this landscape.

Benefits Beyond the Partners

The collaborators also see potential for this partnership to add value to the broader mathematics education field. Because the work is grounded in multiple areas of interest—from technology applications in early elementary education and in mathematics education, to teacher education, from eliciting student thinking and assessment of student learning, to research and practice partnerships and capacity building—there are many different avenues for portrayal and sharing of the work. Indeed, there is much that already has been shared of benefit to education communities by everyone in the partnership. Teachers and administrators are sharing what they have learned with other teachers in their schools and districts. Some of the cohort 1 participants in the partnership have moved to new positions (from teacher to math coach, or from math coach or teacher to administrator), and they are taking what they learned from this partnership to their new districts. Mathematics education faculty are reaching out to new schools to test out the idea of forming additional partnerships. Along with developing tools and research briefs that are widely available to the broader field, and along with mathematics education faculty and school personnel, EDC has been sharing what they have learned through numerous conferences for a diverse array of audiences: mathematics educators, educational researchers, and technology educators and administrators.

Tools and Resources

One of the ways this partnership is contributing to the broader field is in the innovative application of iPad apps to mathematics, and the research on that application. As Louie explained:

One of the most exciting observations that the collaboration came up with was an iPad use that had nothing to do with a content delivery app. It wasn't a math game that taught a specific operation, or it wasn't teaching about math. It was just an audio and visual recording tool. I found that really interesting, and I think there is literature out there about the power of visual representations to help students advance their mathematical learning and thinking, but I haven't seen a lot about the audio part and how that fits in as well, especially at this younger age. It is exciting and interesting to me that this came from the teachers and is something potentially new to the research field.

The tools that have been produced through the research-practice partnership in Maine have included EDC's research briefs on mobile technology and mathematics learning in the early grades, supporting mathematical discourse in the early grades, and productive struggle in mathematics. These briefs have been very useful to the partnership, and are also being used by others. Eliason noted how helpful the briefs have been in deepening the understanding among participating teachers about the foundational knowledge students need to develop their mathematical thinking and discourse skills.

She has also shared the briefs with other teachers and instructional specialists in the district who are, in turn, using them in their practice:

The EDC practice briefs are very useful. I think they are critical and have helped our elementary teachers —some of them have that deep understanding of the content for literature, but not in math. So I have used them with teachers through the learning teams in the six schools I work in. We read the briefs together, and we did some practice diagnosing, ‘Where do you think your kids are here, and what does this mean, and where it is next?’

We have an interventionist here at Sherwood Heights who has been working with 1st graders throughout the year and she’s used the briefs as her lesson plans many times. Together we did an early math assessment and we identified where the kids were on the practice brief progression. There is an activity that goes along with that, and the activities are nice because you can see how you would create other similar activities. So, the interventionist used them a lot.

Other tools and resources that have been shared in presentations of interest to the field include the infographic that EDC created to illustrate the process the partnership has engaged in, and the preliminary implementation guidelines to promote strong mathematical thinking among young students with access to interactive mobile technology in the classroom, which emerged from the inquiry group meeting.

Teacher Leadership

Importantly, many of the cohort 1 participants are taking on leadership roles, sharing what they have learned with other teachers in their districts. Some have moved from teacher to math coach or administrator in other districts and are taking core ideas and practices from the research-practice partnership to other teachers, districts, and schools. As Buffington noted:

Some of the cohort 1 people are really starting to branch out into more leadership. One of those teachers co-presented with me at a conference for elementary teachers using technology. Some of the teachers will be doing a series of videotaping lessons in classrooms next week, and those teachers want to get the word out about the key components of the work they have been doing. The math coach is working with many other teachers and looking to the math education researchers for research to inform the other grade levels as well. So when we are thinking about longer-term capacity building and impact both within and outside of their district, that’s really great.

For example, the district math coach also noted how the partnership had helped to deepen her mathematics understanding, helped her more readily assess and come up with strategies to best help students in mathematics, and provided her with more resources to share with other teachers:

I now have this deep understanding of early math developmental learning progressions. I thought of math as a strand, and kind of disconnected... Let’s say I have a 1st-grader who is really not getting addition, and I really didn’t know what to do and how to diagnose what was up there. So if they couldn’t add 9 plus 6, other than just counting cubes, I would just give more tools and we would do it over again. So I tried to teach it in a different way, but now I have a better understanding that it wasn’t so much that they needed it taught in a different way, it is just that there is something foundational that is not in place yet, and now I have resources and knowledge that allows me to diagnose that, figure out what it is, and target it. I didn’t have that before, and I have shared that with a lot of our teachers...

Dissemination

EDC, along with many of the partners, has been sharing findings from the research-practice partnership in a diverse array of conference presentations, from regional associations of mathematics educators, to mathematics education researchers, to regional gatherings of district technology leads, and those interested in equity. There has been follow-up from participants in these conference presentations who are interested in learning more about the work and findings of the partnership. The mathematics education faculty are working together on a book chapter and have co-presented at conferences. In all of these outlets, Buffington noted how important it is to have the contextual examples of classroom videos and student work that help share the impacts of the project on teaching practice, student learning, and access to high-quality mathematics experiences for all students:

...being able to have contextual examples that can highlight how it has changed teachers' practice, and how classroom cultures have changed... and the broad reach in terms of this being an equity move for all students.

Multiple Audiences

The wide array of audiences to whom this work may be of interest and applicable is a strength of the project, in that it offers opportunities for people with multiple perspectives to come to the table.

Oftentimes, tech educators or educational technologists aren't really grounded in learning research or content-specific applications. Being engaged around the importance of bringing in the math learning research, early learning research along with how to best use the tech, is really important... I have been invited to conferences that are teams of administrators and district tech leads.

This was a central focus of the work of this partnership's inquiry group meeting, held in November of 2014, which was another vehicle for both enriching the work and sharing it with the broader field. As Buffington said:

For the inquiry group, we were really strategic in placing that event in conjunction with something that was already happening, that was drawing other practitioners who had experiences with these mobile technologies together. We wanted to bring together math education researchers as well as technology researchers as well as practitioners so that it was really more lenses on the work, and not just coming from one perspective. It is an additional strategy for cross-cultural exchange, to bring different folks together. It is really helpful as it acknowledges the complexity of the work on the ground... In our case, because we are looking at mobile technology, math, and early learning, we have different types of researchers and different types of practitioners coming at it from different perspectives. It is really critical to design these opportunities from the beginning with equity in mind, and to do that, it is not just a matter of putting the same number of researchers and practitioners together or at a table.

VI. THE CASE AS ILLUMINATIVE OF DESIGN-BASED RESEARCH + PRACTICE PARTNERSHIPS

The Maine partnership between EDC, the Auburn School Department, and the two mathematics education faculty has been a highly successful research-practice collaboration. There is a high level of engagement in the work and, across the board, researchers and practitioners feel as though they are part of an authentic arrangement for improving mathematics teaching and learning. As Buffington eloquently summarized:

Early on, the teachers and principals asked, ‘Who are the researchers? What is the research you are doing?’ And that shifted to, ‘What are we doing?’ and now it is, ‘We want to look at this.’ There’s been an evolving level of understanding of the partnership to where everyone understands that we are co-planning this, we are collaboratively designing and testing things.

Below are some of the main reasons for the success of this partnership and the ways in which it is illuminative of design-based RPPs:

- a partnership and project started from scratch, built on careful precursors, but its own distinct effort that the partners could co-develop from the beginning
- a research-practice partnership that was not constructed around what researchers could share with practitioners, but rather around key areas of common inquiry of interest for mutual investigation
- careful pacing and scaffolding of the work
- the hybrid role that EDC, and Buffington in particular, play (and the evolving hybrid roles of the other partners)
- time devoted to the selection and evolution of the hypotheses and focus questions
- the number of structures for various members of the team to meet, plan, and share their work
- the focus on technology as the area of common inquiry that was new territory for both practitioners and researchers.

The Maine partnership highlights the elements of design-based implementation research: “(a) a focus on persistent problems of practice from multiple stakeholders’ perspectives; (b) a commitment to iterative, collaborative design; (c) a concern with developing theory related to both classroom learning and implementation through systematic inquiry; and (d) a concern with developing capacity for sustaining change in systems” (Penuel et al, 2011).

For example, in determining the *persistent problems of practice* that would be the focus of the work, all the stakeholders were engaged in conversations about what the work would be and where a “shared understanding of the problem that will be taken up among people representing different stakeholder groups” was developed (Penuel et al, 2011). They began from a broad desire to improve mathematics achievement and focus on using technology in early elementary mathematics. They narrowed to the broad set of four hypotheses and finally down to the key focus: ***When students record and review explanations of their thinking when solving mathematical problems, student engagement in mathematics and learning will improve.*** This narrowing took place through the *iterative and collaborative design and concern with developing theory related to both classroom learning and implementation through systematic inquiry*. This was done over the course of several

years, through conversation and discussion of key research ideas, through systematic testing of different implementation strategies, and through observation and joint reflection on what was happening in the classroom. And finally, the partnership highlights the *concern with developing capacity for sustaining change in systems* through the professional development provided to the practitioners, and through the focus on technology being new and of mutual learning interest to both the practitioners and researchers, which allowed them all to take what they were learning and apply it in their respective professional settings. The development of human and social capital was fostered through the ongoing networked improvement community (Bryk et al, 2010) created by the partnership. As this case demonstrates, this network thus far has enabled the partnership to address “the complex problems of practice improvement demand” by bringing to bear “a diverse mix of skills” and “consideration of when and how in the arc of problem solving this diversity of expertise is best exploited.” The partnership exemplifies what Bryk argues—that networked improvement communities constitute new arrangements for disciplined inquiry where the work of research and practice join in a more dynamic and interactive fashion,” and where “strong scholars are invited to engage in applied R&D, but now in quite different ways in the pursuit of a science of improvement.”

The Conjectures

The Maine RPP has been highly attentive to the conjectures, using them as a vehicle to both structure the work and reflect on the work, with reflection happening within the working group at EDC as well as with the broader Research + Practice Collaboratory. The primary conjecture driving the work of this partnership is this: The results of research-practice partnership work will be more usable and useful because they are more responsive and relevant to local contexts. The Maine site has used this as a focus for its work. The persistent problems of practice have been carefully honed over time through the collaborative work of both researchers and practitioners. Perhaps because the initial partnership formation in Maine was somewhat difficult, this partnership was painstakingly crafted. The roles of the hybrid players (at EDC and the district math coach) have been key to this partnership’s development.

The conjecture about process—that jointly negotiated research supports new insights and understanding, including the identification and refinement of new problems of practice, for both researchers and practitioners—summarizes what has happened in the course of this partnership. Parties on all sides have benefited from the partnership, and the time spent in the early part of the partnership developing trust and mutuality—through a series of small and large group meetings, coupled with time for teachers and researchers to try out and reflect on strategies before zeroing in on the area of investigation—was time well spent.

As highlighted throughout the case, both practitioners and researchers experienced new insights and understandings, not only related to using new technologies in early grades mathematics, but also related to the pedagogy of using those technologies effectively. Insights that gave teachers a better understanding of their students’ mathematical thinking also deepened teachers’ content and pedagogical knowledge and their understanding of how best to facilitate student thinking. Teachers have taken what they learned and applied it to other subject areas, and the district math coach has used what she learned with other teachers in the district as well. The math education researchers have gained new insights about teaching and learning in mathematics in the time of the Common Core State Standards—insights that have informed their practice in their pre-service courses.

Perhaps the best example of making accommodations on both sides and developing flexible solutions and strategies was in the spring of 2015, when teachers were focused on trying and sharing strategies related to the recording app. Teachers were concerned that as they moved into this phase of the partnership the professional development they had been receiving from EDC would lessen, and they did not want that to happen. The district math coach communicated with EDC to sustain the professional learning experiences throughout the partnership, which has been beneficial to the teachers.

How the Maine Partnership Has Contributed to the Collaboratory

In addition to the Maine partnership's focus and reflection on the conjectures, the focus on what happens inside the classroom, and the focus on a specific but wide-reaching problem of practice that centered on technology, early elementary mathematics, and pre-service education are unique among the three collaboratory partnerships, effectively broadening the examples of research-practice partnerships the collaboratory offers. As Buffington noted:

I think it is really important for the collaboratory to have examples in these different realms of the work. The Exploratorium work is very much grounded in informing the facilitators in the informal setting. It is also really engaging teachers differently than at the University of Washington, where they are doing curriculum work that is more outside of the classroom. This is just a little closer to the ground. That's important in that it provides us a different range of products coming out of the work.

EPILOGUE

By any measure, the collaboration between EDC and the Auburn School Department has been a highly successful one. The deep and authentic engagement in the work, and the commitment to the creation of an equal partnership of mutual benefit and learning, has been noteworthy.

The only question is one of investment: this case has involved a substantial number of players who have worked deeply with a small number of teachers and mathematics education faculty. Perhaps this is the nature of this work. Perhaps it takes this kind of investment of time and people to create the conditions necessary for a fruitful research-practice partnership. But is it sustainable over the long term? It is important to note that the EDC, higher education faculty, and ASD partners are aware of this concern and revisit it in their work together. The desire is that these newly established relationships between ASD and the university faculty will continue beyond the life of this project, and discussions are underway to find additional funding to support this work and expand it to other grade levels. The case highlights several ways in which the work has begun to extend beyond the core group of practitioners and researchers. One positive sign is that funding received by one of the neediest schools in the partnership is already helping to support additional connections with Shannon Larsen and the University of Maine at Farmington Coaching Project.

The Maine Research + Practice Partnership has continued to develop and build capacity within the Auburn School Department and the University of Southern Maine and University of Maine at Farmington, with much of the work of the past year focused on disseminating the tools, resources, and work of the partnership.

The partnership has written proposals for principals, the math coach, and university faculty to present the partnership work at NCSM and NCTM as well as at smaller statewide mathematics and technology conferences. The partnership also hosted an inquiry group meeting in fall 2016, and continues to develop a collection of resources around topics generated at that meeting.

The partnership has offered workshops about using iPads in K-2 mathematics to other schools and districts throughout Maine. For example, after a presentation at a statewide technology conference, the partnership was contacted by a school district and gave a workshop for 35 of their elementary teachers. They also gave a workshop to all of the teachers in a small school in northeast Maine.

We are really in a good place of deepening, extending, scaling up, and sustaining the work.

Perhaps the most significant development in the evolution of the Maine partnership is the recent awarding of a statewide MSP grant. This grant will continue to add capacity to K-2 teachers in the current schools, expand the work into grade 3, and extend the math iPad research, practice, and teacher leadership development to 22 additional schools throughout Maine. The capacity building of this grant also extends to the two partner universities through the involvement of two additional faculty—a mathematics methods faculty member and a technology integration faculty member. This will deepen the reach of the partnership work within the universities as well. The statewide partnership will be led by a design team that includes the math coach, one principal and central office staff from Auburn, one representative each from the two universities, five cohorts of teachers representing the geographic range of the 22 new districts, and EDC staff. The 22 districts were chosen because they have implemented mobile technology in the early grades in their schools and were looking for good strategies for working with teachers and students. The tools, resources, briefs, and video clips created by the existing partnership will be utilized in the larger statewide MSP project work.

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