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Editorial

Data in a Brave New World: Reducing Isolation to Amplify the Impact of Educational Research on Practice

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In our November 2017 editorial (Cai et al., 2017), we presented a vision of a future in which research has a significant impact on practice. In the world we described, researchers and teachers work together, sharing similar goals and incentive structures. A critical feature of this brave new world is the existence of an online professional knowledge base comprising "useful findings and artifacts that are continuously refined over time, indexed by specific learning goals and subgoals, and that assist teachers and researchers in implementing learning opportunities in their classrooms" (p. 469). Moreover, we argued that teacher–researcher partnerships are a necessary condition for greater impact on practice.

In this editorial, we contend that these partnerships alone are not sufficient to overcome all obstacles preventing research from meaningfully impacting practice. Although close partnerships between researchers and teachers would dramatically alter the dynamic between research and practice by bringing research into the classroom, such partnerships alone would have a limited effect on the broader landscape of mathematics education.

Recall that the protagonists of our November 2017 story, Ms. Research and Mr. Lovemath, were building research-based solutions to Mr. Lovemath's problems of teaching. At the same time that Ms. Research and Mr. Lovemath were working together toward their solutions, another partnership might have been working to solve similar problems in a neighboring district, with no communication occurring between the groups. Indeed, many teacher–researcher partnerships around the country could be operating simultaneously, reinventing solutions to similar problems. Even the most productive teacher–researcher partnerships are severely constrained if they cannot easily access what other partnerships are learning about solving similar problems of teaching. Isolation is, we believe, one of the major obstacles to building a knowledge base that could amplify the impact of research on practice.

In this next series of editorials, running through 2018 and perhaps beyond, we will address methods for surmounting the obstacle of isolation in conducting practice-relevant research.[1] We will place ourselves in the world we imagined in

[1] We paused from this line of thought in our January 2018 editorial (Cai et al., 2018) to focus on the role played by replication in educational research in general and mathematics education research in particular, a theme to which we will return in a later editorial.

our November 2017 editorial and propose ways of connecting teacher–researcher teams to build knowledge that increases its reach to more and more students. Although the culture that brings together teachers and researchers still seems far off in the future, the technologies we will describe that could connect these teams are currently available. So, the methods we will propose to connect research teams could be implemented tomorrow. However, the data that these teams need in order to improve practice, the data that the proposed methods will process, depend on cultural changes in teacher–researcher relationships that may require more time to develop.

Despite the challenge of changing cultures, and believing that the methods we propose could accelerate the needed cultural changes, we launch this next series of editorials by considering further the problem of isolation and then describing a form of data collection and sharing that could link teacher–researcher partnerships into virtual research communities. As we indicated at the beginning of 2017, some of the observations that we make and recommendations that we offer will be unconventional and perhaps even controversial. Our purpose remains to provoke discussion and stimulate a flow of new ideas in our field about how to close the long-standing, stubborn gap between research and practice.

Variation and Isolation

Education, and mathematics education specifically, faces a long list of problems and conditions that widen the gap between research and practice. Near the top of the list is the fact that researchers, and even teacher–researcher partnerships, work in isolation. Researchers pursue a dizzying array of teaching and learning questions. The limited degree to which researchers share common ground in research questions, local theories, interventions, and assessments contributes to the challenge of building a shared knowledge base and, in particular, a shared knowledge base that is useful to practice. There is little common ground that enables data to be productively shared or aggregated. Moreover, variations from one context to another and fluctuations from year to year in learning goals, curricula, students, and teachers mean that teachers and researchers are forced to continually start over to test improvements to teaching. The (understandable) perception that every teacher works in a unique context (Gallimore, 1996) decreases demand for better, empirically tested teaching methods and curricula (Elmore, 1996). If every classroom is unique, what guarantee does a teacher have that teaching methods and curricula that have been empirically tested in other teachers' classrooms will bring similar benefits to his or her own classroom?

Variations across classrooms pose one set of problems; variations within classrooms pose another. To tailor their instruction to meet each student's needs, teachers would ideally trace individual students' thinking and learning trajectories at a fine-grained level. This is part of the rationale fueling data-driven instruction (Hamilton et al., 2009). Yet, on the practical level of a single teacher with a classroom full of students, collecting and keeping track of the development of each student's mathematical thinking along a particular learning trajectory or multiple learning trajectories is intractable (Nuthall, 2004). Working alone, without the benefit of sharing data across settings, even teacher–researcher partnerships are severely constrained in collecting and using data to solve these fundamental instructional problems.

If every classroom were completely unique, and if every student were completely different, the problem of isolation would be impossible to solve. Teacher–researcher partnerships would necessarily be working to solve different problems, and solutions would not be shareable. However, despite individual idiosyncrasies, there are patterns across students, across classrooms, and across problems that teachers face every day (Ball & Forzani, 2009; Lampert & Graziani, 2009; Rothkopf, 2009). It is these commonalities that unlock the potential solutions to isolation. Furthermore, recently developed technologies stand ready to take advantage of these commonalities. These technologies offer new methods to connect teacher–researcher teams into networks that can build useful knowledge bases and, in turn, amplify the impact of research on practice. More specifically, the technologies available to gather and share data have evolved rapidly in recent years and now afford teachers, researchers, and teacher–researcher partnerships new opportunities to build on each other's work to solve shared problems. We devote the remainder of this editorial to discussing the changes to how, in this new world, researchers and teachers could engage with data and data collection to address some of the problems identified above.

The Nature of Data and Data Collection as an Antidote to Isolation

At least three kinds of data commonly used by researchers today could help reduce the isolation of researchers and teacher–researcher teams. The first kind is raw data, including large-scale data on student learning. This type of data is often used by researchers to conduct secondary analyses (e.g., using PISA, TIMSS, or NAEP data). The second kind is data gathered to answer particular research questions addressed by specific studies. This category includes the kinds of data generated by the teacher–researcher partnerships we have described as well as data from research studies common in mathematics education today. The third kind is data contained in publications that disseminate research findings, including journal articles, practitioner-focused resources, and policy and curriculum documents. Data from this category, presented in journal articles that provide sufficient methodological detail, are frequently used by researchers as the raw material for conducting meta-analyses and other high-level reviews. In the brave new world that we envision, new methods of gathering, archiving, and sharing these same kinds of data will make it possible to connect research teams and create virtual communities of teacher–researcher partnerships.

How can the nature of data collection and processing reduce isolation and bring research teams together? A first step is to acknowledge that many teachers, in many different contexts, try to help their students achieve the same learning goals. Teachers using the same curriculum and teaching at the same grade level are likely members of such communities. Once teacher–researcher partnerships communicate with other teams working toward the same learning goals, there is common ground for recognizing similar instructional problems and asking similar research questions. At this point, the demand will increase at each site for the knowledge gained at other sites. Data gathered at one site will become interesting to other sites that share the same instructional problems. The value of common assessments becomes evident, and members of these communities can then see the value of shared data.

These shared communities can begin forming when a few teacher–researcher partnerships recognize their shared instructional problems. The shared conditions do not need to exist everywhere for this process to begin. They simply need to exist in enough locations so that teachers and researchers see the benefits of sharing data by recognizing that what is learned about solving an instructional problem at one site can inform the solution to the same problem at other sites. Indeed, multiple efforts can run in parallel, allowing different clusters of researchers and teachers to coalesce on the basis of their shared learning goals, problems, and assessments. Nonparticipating sites might see the benefit of joining a participating site by adopting shared learning goals and assessments. This could serve as a research-based, market-driven process to gradually enlarge the community of sites that share the same learning goals for their students. Multiple cycles of testing and improvement (i.e., replications) could be enacted in a brief time; materials could be tailored to students in different locations or, more to the point, to students with different learning trajectory profiles.

It is not difficult to see how aggregating data around common learning goals and instructional activities aligned with these goals could rapidly evolve into a shared professional knowledge base. In the teacher–researcher partnerships of the future, information about the development of students' mathematical understanding could be collected on a regular basis using the same instruments and tools across schools, districts, and even countries. Those data, along with instructional materials developed by the partnerships, would represent the collective knowledge of the profession. Upon completing analyses, researchers could contribute their findings back into the knowledge base in multiple ways that speak to different audiences. In addition to journal-appropriate research articles that report findings, practical, usable findings could be included in the knowledge base in an abbreviated form usable by practitioners, focusing on those results that could readily be put to use to improve practice around a particular learning goal. Data in the knowledge base would accumulate and evolve through an iterative process, with teachers and researchers continuously contributing to, updating, and using data. The knowledge base would be made searchable and easily accessible by indexing the information by learning goals or research questions.

As the amount of data related to a learning goal increases and encompasses more contexts, overarching analyses could help illuminate patterns in variation that would guide future users of the knowledge base to information that is relevant to their students and contexts. In fact, the data and findings gathered by teacher–researcher partnerships working on similar problems at different sites could be considered a form of conceptual replication that investigates variation, identifying contextual factors that influence the effects of instructional activities or lessons. Meta-analyses could be used to identify patterns in effects associated with profiles of contextual factors. As we argued in our January 2018 editorial (Cai et al., 2018), replication studies play an important role in strengthening confidence in published research findings, and conceptual replications have the potential to both strengthen support for the effectiveness of practices as well as identify the contexts in which particular practices are and are not effective. Moreover, the combined activity of multiple teacher–researcher partnerships working on similar problems would generate large amounts of student- and teacher-level data to which researchers could apply secondary analyses. These analyses could then inform the future work of teacher–researcher partnerships, creating a feedback loop that would help mitigate the effects of isolation between partnerships operating in different contexts. Among other things, this would help teachers provide equal opportunities for all students to engage with mathematics by identifying learning opportunities that are effective for students with different learning needs.

Technologies That Could Enable Virtual Teacher–Researcher Networks

Although the extent of data and knowledge sharing among researchers and teacher–researcher partnerships that we have described in this brave new world is greater than it is today, the need for such radical sharing has already been recognized by policy makers and researchers, whether in mathematics education or in other research domains (American Educational Research Association [AERA], 2017; Center for Open Science, 2017; Institute of Education Sciences, n.d.; National Research Council, 1985). Technological mechanisms have been actively developed in recent years that make it feasible to store, share, and access data to address shared research questions.

A recent workshop sponsored by AERA and the National Science Foundation focused on issues of data sharing at the article-publishing stage. Representatives from a wide range of research associations and journals including the National Council of Teachers of Mathematics and *JRME* collaborated to articulate a vision for data sharing and research transparency. One key point of discussion centered on the role that journals could play in encouraging the sharing of research data, including encouraging or requiring researchers to share their data in a data repository as a condition of publication. Several data repositories were represented at the workshop, including the Inter-university Consortium for Political and Social Research (https://www.icpsr.umich.edu), the Databrary (https://nyu.databrary.org), and the Qualitative Data Repository (https://qdr.syr.edu). These repositories are currently able to archive multiple forms of research data, including text, audio and video recordings, and student assessment data. Both quantitative and qualitative data are supported, and some repositories include tools for organizing and analyzing data (e.g., manipulating video data). Moreover, the repositories index the information they collect by tagging it with useful identifiers, and they include contextual information needed to interpret data sets properly. Access to sensitive data can be controlled, and researchers can specify which of their data can be used and under what circumstances.

These repositories are currently focused on archiving only some of the types of data that we discussed above. They are intended to allow researchers to share their data with other researchers who might then conduct an exact or a conceptual replication. Yet, the impetus for researchers to engage in this kind of collaborative data sharing is analogous to the impetus for teacher–researcher partnerships to share data on similar instructional problems. The shared professional knowledge base that we have described could be a natural extension of these research data archive projects, going beyond researcher-to-researcher data sharing to include networks of teacher–researcher partnerships along with the types of data and findings that would be most useful to them.

Discerning Concrete Steps Leading to a Brave New World of Data

What we have proposed in our editorials about this brave new world is clearly aspirational. To preclude readers from too easily dismissing these ideas as pie-in-the-sky dreams, we suggest some concrete steps that the mathematics education community could take to bring us closer to this new world.

As an editorial team, we believe a first step would be for our community to consider whether the time has come for researchers who publish in *JRME* and other prominent mathematics education research journals (Williams & Leatham, 2017) to routinely share their data in one of the available repositories (particularly in the case of research published by teacher–researcher partnerships). AERA plans to adopt this policy (AERA, 2017), and it is already expected practice in other social science research domains, including political science (data sharing is the policy for the *American Journal of Political Science*; see also Lupia & Elman, 2014) and economics (data sharing is the policy for publication in the *American Economic Review*, the *Journal of Political Economy,* and *Econometrica*).

As a second step, fostering data sharing in mathematics education research could dovetail with developing funding proposals to establish and test professional knowledge bases in collaboration with one or more of the existing data-sharing repositories. These projects could create teacher–researcher partnerships that would begin to populate and make use of knowledge bases. To enable this work, a special conference or working groups at existing professional conferences could be established to begin implementing these ideas.

Finally, any discussion of steps to develop a professional knowledge base should consider concrete measures that would address equitable[2] access to the knowledge base and to participation in the teacher–researcher partnerships that would build the knowledge base. In particular, teachers in all schools should have opportunities to join teacher–researcher teams, not just teachers in privileged schools located near universities. Given our contention that isolation, whether among teachers,

[2] Thus far in our editorials, we have only implicitly considered issues of equity in the brave new world. In future editorials we will directly address these issues in more detail.

researchers, or teacher–researcher partnerships, is a fundamental problem, teachers working with marginalized and economically disadvantaged populations, who may be most likely to be working in greatest isolation (Bridwell-Mitchell, 2017), should be included early in the creation of teacher–researcher partnerships and the development of a professional knowledge base.

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