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Editorial

Making Classroom Implementation an Integral Part of Research

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In our May editorial (Cai et al., 2017), we argued that a promising way of closing the gap between research and practice is for researchers to develop and test sequences of learning opportunities, at a grain size useful to teachers, that help students move toward well-defined learning goals. We wish to take this argument one step further. If researchers choose to focus on learning opportunities as a way to produce usable knowledge for teachers, we argue that they could increase their impact on practice even further by integrating the implementation of these learning opportunities into their research. That is, researchers who aim to impact practice by studying the specification of learning goals and productively aligned learning opportunities could add significant practical value by including implementation as an integral part of their work.

A Story About Implementing Realistic Mathematics Education

As usual, we begin by sharing a story. This time, we were inspired by an article by Gravemeijer, Bruin-Muurling, Kraemer, and van Stiphout (2016) about challenges to implementing Realistic Mathematics Education (RME) in the Netherlands. RME is a well-developed, research-based curriculum that carefully creates learning opportunities linked to well-specified learning goals. This process is reminiscent of the research approach we described in our previous editorial (Cai et al., 2017). In addition, RME builds in supports that researchers believe are important for helping teachers implement the curriculum as intended. Instances of teachers using RME to provide opportunities for conceptual learning can be seen in videos from the TIMSS 1999 Video Study (Hiebert et al., 2003).

In their article, Gravemeijer et al. (2016) probed the failure of classroom teachers to implement RME in ways that would enrich students' conceptual understanding of mathematics in three mathematical domains. The authors discussed the findings of three independent studies of implementing RME-based textbooks that aimed to identify reasons for lower-than-expected student proficiency in subtraction under 100, fractions, and algebra, respectively. Findings from all three studies highlighted a common root to the lower-than-expected student proficiency problem: a phenomenon called "task propensity," which is "the tendency to think of instruction in terms of individual tasks that have to be mastered by students" (p. 26). This phenomenon can lead, in turn, to a focus on learning procedures that result in quick solutions to particular sets of tasks rather than fostering students' conceptual understanding of the underlying mathematical concepts involved in those tasks.

Gravemeijer et al. (2016) argued that although the textbooks (and curriculum guidelines) attend to conceptual understanding, they stop prematurely in the conceptual development process. This limits the horizon that teachers see when they use the materials. After presenting this argument, Gravemeijer et al. (2016) write: "We cannot, however, blame the textbooks or the teachers for not aiming for more advanced mathematical understandings, for more advanced conceptual mathematical understandings were not formulated as educational goals in the mandated curriculum in The Netherlands" (p. 36). Thus, although the curriculum was designed around RME-based goals of conceptual understanding, it did not incorporate more advanced conceptual goals throughout the duration of the learning sequence. Intended learning goals were unrealized because "attention was shifted toward procedures that generated answers for specific tasks . . . the result was that the students did not reach proficiency on the level of more advanced conceptual understandings" (p. 39).

The findings of Gravemeijer et al. (2016) reveal a potential gap between the research-based design of a curriculum and its enactment. According to our interpretation of the findings insightfully presented by Gravemeijer et al. (2016), this gap is associated with issues of implementation: Although the RME curriculum was carefully developed with a basis in research, and although it included supports for teachers, implementation was not embedded as an ongoing focus of RME researchers' development of the curriculum. In fact, to our knowledge, no curriculum in mathematics education integrates implementation with development and research in an ongoing, continuous way. The significance of this analysis is that even though RME is a well-developed, research-based curriculum with supports for fostering students' conceptual understanding, without an explicit and ongoing integration of implementation into the research agenda, the intended goal of facilitating students' conceptual understanding failed to be fully realized.

Implementation as an Integral Part of Research

It is not surprising that curricula, and educational innovations in general, are not always implemented as intended. Forty years ago, Fullan and Pomfret (1977) highlighted the issues of implementation:

> Once an innovation was planned and adopted, interest tended to shift toward the monitoring of outcomes. The assumption appears to have been that the move from the drawing board to the school or classroom was unproblematic, that the innovation would be implemented or used more or less as planned, and that the actual use would eventually correspond to planned or intended use. The whole area of implementation, what the innovation actually consists of in practice and why it develops as it does, was viewed as a "black box" where innovations entering one side somehow produce the consequences emanating from the other. (p. 337)

This lack of attention to implementation was viewed as problematic by some educators because it failed to attend to the fidelity of implementation of an innovation to consider how closely teachers' actions in the classroom reflected the intentions of the innovation's designers. In response, Fullan and Pomfret (1977) called for the inclusion of an explicit implementation component when the effectiveness of an innovation is evaluated.

In recent years, there has been increased interest in research that investigates the effectiveness of curricula on students' learning by taking implementation into consideration (Century & Cassata, 2016; Lloyd, Cai, & Tarr, in press; Morris, 2012; National Research Council, 2004; Remillard, 2005). It has become "a phenomenon in its own right" (Fullan & Pomfret, 1977, p. 336). It also has its own label, *implementation research* (Century & Cassata, 2016; Nilsen, 2015), and its own journal in the medical profession, *Implementation Science*. According to Schoenfeld's (2016) review of research in mathematics education, a recognition during the 1980s that educational innovations needed to be followed into the classroom marked a significant shift in research approaches. Clearly, issues of implementation are no longer being ignored.

The point we wish to add to this discussion is that even when researchers attend to implementation as a phenomenon, they often view implementation as a separate process. Designing and testing an intervention is often seen as a first step. Implementation of the intervention is seen as a follow-up study with its own set of research questions. Sometimes, the details of the daily implementation are just left to the teacher. The story reported by Gravemeijer et al. (2016) is especially telling because even when researchers are integrally involved in developing and researching a curriculum with careful supports for teachers, leaving the ongoing implementation of the curriculum as a follow-up task for teachers can expose a gap between research and practice.

The point we wish to make in this editorial is that including studies of implementation might not be enough. If researchers hope to impact practice, they might need to embed implementation as an inseparable aspect of intervention design. If researchers leave implementation to teachers, or if they study implementation as a phenomenon separate from the design of an intervention (e.g., writing and testing curricula), they could miss a chance to boost the impact of their work.

Conducting Research With Implementation as an Integral Part

What would research with implementation as an integral part look like? How should we conduct such research? Some clues can be gleaned from design research. Design research, with its emphasis on iterations of studying the effects of an intervention and using the information to refine the intervention, captures some important aspects of embedding implementation with the creation and testing of learning opportunities (Cobb, Jackson, & Dunlap, in press; Collins, Joseph, & Bielaczyc, 2004).

An example of design research that illustrates our view of what this work could entail is found in a series of experiments that Gu, Huang, and Gu (2017) refer to as "a Chinese version of 'design-experiment'" (p. 18). One experiment by Gu et al. focused on the concept of perpendicular lines. The goal was to find and implement a sequence of learning opportunities within a lesson that best helped students construct a robust concept of perpendicularity. In many cases, the opportunities created were a sequence of slightly varying problems, diagrams, and examples. Each trial of these opportunities involved a cycle of planning, implementation, evaluation, and improvement, with one experiment consisting of 50 such cycles. Our vision of integrating intervention research with implementation borrows from this idea of recurring experiments in which implementation itself becomes the source of information that guides refinements in learning opportunities. In the experiments described by Gu et al., the creation of learning opportunities could not have proceeded without attending to their implementation.

Another lesson that can be learned from the Gu et al. (2017) experiments is that research that tightly connects intervention with implementation is based on the assumption that the purpose of educational research is to solve problems teachers face in their practice. We believe that such an assumption could define a promising path for research that aims to have a higher impact on practice. If research is not solving teachers' problems, why would teachers want to use the research findings? This assumption is precisely what underlies much work in other professions that have a high impact on practice: The purpose of the work is to solve the users' problems (Bryk, Gomez, Grunow, & LeMahieu, 2015; Langley et al., 2009). Teachers are the ones who ultimately implement instructional activities and create learning opportunities for students. If research is to improve the quality of these learning opportunities, it is inevitable, from this perspective, that research offer information on effective ways to implement these opportunities.

If mathematics education researchers take this assumption seriously, they face an immediate problem. Teachers work in a wide variety of contexts and face a variety of different problems. Research that aims to help a teacher implement learning opportunities effectively might improve implementation in that teacher's classroom with those particular students, but would this work have an impact on other classrooms? Does research on implementing learning opportunities need to be conducted for each teacher? Given the ratio of researchers to teachers, this presents a serious, perhaps insurmountable, problem to this approach for impacting practice.

Fortunately, teachers who are working toward the same learning goals for their students do not face entirely different problems. Teachers across a variety of contexts encounter similar problems as they implement instructional activities to create productive learning opportunities (Ball & Forzani, 2009; Lampert, 2003; Rothkopf, 2009). These problems have high leverage for researchers. Helping teachers solve shared problems allows the impact of research to extend far beyond the individual classrooms in which the research is conducted.

For example, a learning goal for many fourth-grade students in the United States is to understand how to multiply multidigit whole numbers using concepts of place value (National Governors Association for Best Practices & Council of Chief State School Officers, 2010). Students are likely to encounter the place-value-based procedure in which the second partial product shifts one position to the left, perhaps with a zero inserted in the ones position. In this case, a learning goal for students becomes understanding why they should place a zero in this position. Fourth-grade teachers with different classes of students might find that slightly different implementations of similar learning opportunities work better for their students. But the problems these teachers face in helping students understand the reason for placing (or not placing) a zero in the ones position are similar enough that what researchers learn about productive implementations in one class will likely be useful for many teachers. Such information could be shared by recording it in annotated instructional activities, perhaps consisting of a sequence of problems or questions that the teacher can pose (see the sample referenced earlier and described in Gu, Huang, & Gu, 2017).

We cannot anticipate the approaches researchers will invent to conduct research that integrates implementation with intervention. Researchers who take up the challenge we pose will need to work out the details of this process. The message of this editorial is that the process is likely to have a greater impact on practice if implementation is embedded in an ongoing cycle of defining learning goals, creating learning opportunities, and improving them by monitoring their effectiveness in real classrooms.

For mathematics education researchers to leave implementation as a separate activity is akin to devising a research question or hypothesis but letting someone else perform the experiment. At the same time, if mathematics education researchers decide to include implementation in a serious way in their research agendas, the effects will surely touch many stakeholders, including teachers, curriculum developers, and funding agencies. Even for researchers, the changes will be significant in more than just theoretical and methodological ways. In our editorials in upcoming issues, we will consider some of the consequences of conducting research that takes seriously the goal of closing the gap between research and practice. In particular, we will examine the consequences for the people involved in this work and the transformation in the roles they traditionally play.

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