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Editorial

Clarifying the Impact of Educational Research on Learning Opportunities

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In our last editorial, we considered the impact of research on students' learning. In clarifying our perspective, we answered the question of "impact of research *on* what" to include both cognitive and noncognitive outcomes in students as well as long-term impact on students that goes well beyond short-term cognitive impact. A natural next step is to examine the conditions under which students can achieve such broad goals. We will devote the next set of editorials to exploring ways in which researchers can design their work to increase its impact on students' opportunities to achieve these goals.

We begin our exploration by focusing on the learning goals and learning opportunities that guide classroom instruction. Although research has shown that factors outside of school have a larger effect on students' learning than their experiences in the classroom (e.g., Lave, 1988; Nye, Konstantopoulos, & Hedges, 2004; Resnick, 1987; Rockoff, 2004), classroom instruction is still considered a central component for understanding the dynamic processes and organization of students' thinking and learning (e.g., Bruner, 1998; Gardner, 1991; Rogoff & Chavajay, 1995; Stigler & Hiebert, 1999). In addition, learning opportunities are something that educators can address directly and something that can be influenced by educational research. In this editorial, we try to clarify what we mean by the impact of research on learning opportunities. As in our first editorial, we begin with a story.

A Fraction Activity Using a Number Line

With the guidance of a mathematics education researcher (Ms. Research), a fourth-grade teacher (Mr. Lovemath) introduced the following fraction task to his students: Order the fractions 7/9, 2/4, 9/10, 6/13, 1/2, 9/5, and 3/7 from smallest to largest, and place them on the number line. This task was part of the fourth lesson in the fractions unit. In the first three lessons, students had been introduced to the definition of fractions, the meaning of fraction symbols, and equivalent fractions.

Ms. Research and Mr. Lovemath chose this task for three reasons. First, this is a cognitively demanding task. Ms. Research is well aware of studies showing that the nature of instructional tasks determines the learning opportunities they provide. Doyle (1988) argued that instructional tasks with different cognitive demands are likely to offer different kinds of learning opportunities. Tasks determine not only students' attention to particular aspects of content but also their ways of processing information. Regardless of the context, cognitively demanding tasks can invite exploration, reflection, and hard work (Hiebert & Wearne, 1993; National Council of Teachers of Mathematics, 2000; Stein, Grover, & Henningsen, 1996). Instructional tasks that are truly problematic and involve significant mathematics, therefore, have the potential to provide intellectual contexts for students' mathematical development and to engage students in productive struggle.

The second reason for choosing this task is the potential role the number line can play in fostering students' learning. In contrast to students' learning about whole numbers, students are expected to learn that fractions are both part–whole comparisons and numbers (Behr, Harel, Post, & Lesh, 1992; Pantziara & Philippou, 2012). The visual number line is often thought to help students make the abstract concept of fraction-as-number more concrete. In fact, the *Common Core State Standards for Mathematics* (National Governors Association Center for Best Practices & Council of Chief State School Officers, 2010) explicitly calls for students to develop an understanding of fractions as numbers on the number line. Ms. Research and Mr. Lovemath selected this task from the curriculum precisely because it could help address this Common Core standard as well as the fourth-grade Common Core standard regarding comparing fractions.

Finally, the third reason for choosing this task is that it allows for multiple strategies to be used to compare the fractions. When students use different solution strategies, they are able to draw on any piece of knowledge they have learned and justify their ideas in ways they feel are convincing. Therefore, students can develop their strategic competence and adaptive reasoning (Kilpatrick, Swafford, & Findell, 2001) as they creatively problem solve in this context. This, in turn, affords students the opportunity to make stronger connections and develop deeper understanding of the fraction ideas involved.

Mr. Lovemath divided his students into small groups to work on the fraction task. However, after 20 minutes, none of the groups were able to come up with a correct solution, much less one they could explain, and the students became frustrated. Mr. Lovemath felt compelled to provide a hint and suggested that the students make use of equivalent fractions using a common denominator, which they had studied in a previous lesson. This not only reduced the cognitive demand of the task but also made the students' solutions quite procedural.

Why did the students encounter difficulties in solving this problem from their curriculum? Why did the intended opportunity to learn not materialize? Whose fault was it? Did the teacher fail to understand the situation or react to it properly? Did the curriculum developers design a task for which the students were not sufficiently prepared? What additional roles could Ms. Research have played? Answers to these questions are critical because this kind of story repeats itself thousands of times every day in classrooms that aim to provide students with broader, richer, and more ambitious learning goals.

Often, unrealized learning opportunities like these have been attributed to teacher deficiencies. Teachers are frequently blamed for reducing the cognitive level of the task because they do not properly facilitate students' learning (Henningsen & Stein, 1997). Although we might criticize Mr. Lovemath's choice to give a hint, this does not address the primary issue of why his students had more difficulty than expected grappling with the task in the way the curriculum developers intended. What do researchers need to know to assist teachers like Mr. Lovemath in making this learning opportunity more productive and thus helping students achieve broader and richer learning goals?

Research and Learning Opportunities

Even though we believe that this task can provide rich opportunities for students' learning, we suspect that the pace of the lessons in which it appeared was too fast for students to develop robust understandings of key preliminary concepts, such as the meaning of fraction symbols, unit fractions, and equivalent fractions. Depending on the nature of the previous lessons, it could be that the only solution strategy available to students was to use the common denominator algorithm. Thus, there was likely a misalignment between the rich learning opportunities the task was intended to foster and the learning opportunities actually available to the students. Ultimately, the students did not attain learning goals in prior learning experiences that would have adequately prepared them to take advantage of the learning opportunities offered by this task.

This story highlights a specific difficulty in our more general quest to increase the impact of research on practice. As we concluded in our last editorial, the construct of learning opportunities can provide researchers with a way to think about influencing practice. Research has shown that in order to foster students' learning, they should be provided with opportunities to engage in productive struggle with cognitively demanding tasks that are neither too easy nor too challenging. However, in this story, the intended learning opportunities seemed to be inaccessible to the students because of a mismatch between the demands of the task and the learning opportunities the students had previously experienced.

Although a mathematics task can be very rich, the learning opportunities it offers are always defined by the prior learning necessary for students to engage with the task. The relationships among learning opportunities and sequences of learning opportunities form a space within which researchers can work to generate results that are useful for practice. For any mathematical task, researchers could ask a series of questions that might lead to increasing the learning opportunities afforded by the task: What are the learning subgoals that a student needs to attain in order to make progress toward achieving the main learning goal of this task? How specific do these subgoals need to be? What are the learning opportunities needed to achieve those subgoals? How do we help students access these prior learning opportunities? What kinds of learning opportunities are best aligned with specific subgoals *X*, *Y*, and *Z* to help students achieve primary goal *A*, and in what order are they best addressed?

We want to draw attention to two features of these questions. First, answering the questions requires breaking down a primary learning goal into finer grained subgoals. In our previous editorial, we argued for broadening the learning goals that researchers should consider. We now argue that once major learning goals have been determined, a good deal of empirical work remains to unpack those major goals into smaller subgoals. Broadening learning goals is important to opening up the research space, but so is identifying the smaller goals implicit in the broader learning goals.

A second feature of these questions is that they are legitimate questions for researchers to address and should not just be left to curriculum developers to figure out. At their heart, these are empirical questions. For the fraction task, researchers would need to empirically investigate which subgoals are truly necessary, and which might be helpful, for achieving the overall goal of the fraction task. Because investigating these questions is best done in the context of actual classroom activity, the research findings would not need a complex translation into practice. Instead, teachers, who likely would be working alongside researchers, could directly apply (and test) these findings in their classroom practice.

Reconsidering Learning Opportunities

One of the most robust findings of education research is that students learn best that which they have the opportunity to learn (Bransford, Brown, & Cocking, 2000; Kilpatrick et al., 2001). Thus, it is incumbent on researchers to investigate how to align learning opportunities with learning goals. Moreover, research will have a greater impact on students' achievement of a primary learning goal if it can inform teachers about how learning opportunities can be created that correspond with the relevant learning subgoals for that primary goal. Researchers should not feel satisfied by simply unpacking primary learning goals into component subgoals. To support practice, additional research is needed to uncover the learning opportunities likely to help students achieve each subgoal (Morris & Hiebert, 2011). Of course, these twin findings—learning subgoals and their accompanying learning opportunities—will quite naturally go hand in hand as researchers investigate the most productive subgoals for a larger goal.

Fortunately, mathematics educators already have some useful conceptions of what this kind of research could look like. Simon's (1995) concept of "hypothetical learning trajectories" (p. 133) captures the idea of a carefully sequenced set of learning opportunities that help students build toward milestone learning goals. Our earlier claim that identifying relevant learning subgoals is an empirical issue means that researchers can contribute to practice by turning the "hypothetical" into the empirically supported. The works of Clements and Sarama (2007); Confrey, Maloney, and Corley (2014); Hackenberg and Lee (2015); Lobato and Walters (in press); Norton (2008); and Steffe (2001) illustrate this process. In addition, methodologies that could be used in this kind of research are being actively developed and refined. For example, design research (Cobb, Jackson, & Dunlap, in press; Gravemeijer, Bowers, & Stephan, 2003) and approaches that build from improvement science (Bryk, Gomez, Grunow, & LeMahieu, 2015) seem tailored for investigating these finer grained questions of identifying critical subgoals and creating productive learning opportunties aligned with these goals.

In some countries, efforts to investigate productive learning sequences have taken different directions from what is typical in the United States. In China, for example, there has long been a tradition of "teaching research" (*jiaoyan*) based on a teacher−researcher model (Huang & Bao, 2006; Paine, 1990; Paine, Fang, & Jiang, 2015). In Japan, the lesson study model represents a distinct but related form of research (Lewis & Perry, 2017; Stigler & Hiebert, 1999). These approaches represent research-based systems that search for increasingly productive learning sequences that identify both an important sequence of learning goals and corresponding learning opportunities. We are not proposing these models as the only, or even the best, ways to identify subgoals and learning opportunities. Rather, the existence of these models in some countries serves to highlight the kind of research findings we are describing.

To reiterate, educational researchers need to consider how to best create the learning opportunities needed to maximize the impact on students' learning. Prior research has established a basis for this line of work, but systematic research is needed to map out the appropriate grain size for learning goals along with productive learning opportunities. For that to happen, mathematics education researchers would need to adopt a different perspective on conducting research than that held by many educators today. This brings us to one of those "thought-provoking" issues we promised to raise in these editorials. It seems to us that, consistent with the current research model, many researchers address questions of theoretical or personal interest. This can lead to results that need extensive translation to reach the grain size teachers need to plan lessons. Researchers and teachers both know the obstacles inherent in this model that prevent the use of such research. However, the kind of work we propose—research that produces findings about the learning opportunities that are needed to achieve particular learning goals—is much closer to the daily work of mathematics teachers. If researchers wish to make this kind of an impact on practice, the alternative model we describe in this editorial is worth considering.

We stated in our first editorial (Cai et al., 2017) that we believe a critical first step in increasing the impact of research is to seek to understand the fundamental reasons for the divide between research and practice. In this editorial, we have suggested that one reason for the lack of impact is that researchers sometimes fail to recognize the small grain size teachers must consider as they help students move from one idea to the next. Tackling issues of learning goals and learning opportunties at this level of detail is one approach that could increase the impact of research on practice. In our next editorial, we will explore the related question of how research might inform practice at the level of teachers' implementation of instructional activities.

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