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Editorial

Addressing the Problem of Always Starting Over: Identifying, Valuing, and Sharing Professional Knowledge for Teaching

Jinfa Cai, Anne Morris, Charles Hohensee, Stephen Hwang, Victoria Robison, Michelle Cirillo, Steven L. Kramer, and James Hiebert
University of Delaware

Arthur Bakker
Utrecht University

John Dewey once said that one of the saddest things about U.S. education is that the wisdom of our most successful teachers is lost to the profession when they retire. Dewey was highlighting a continuing problem in many educational systems: New teachers must start over as they develop effective lessons. They cannot pick up where the retiring teachers left off. There is no widely shared professional knowledge base developed by previous teachers which novice teachers can use to start at a better place than their predecessors. The teaching profession suffers from "collective amnesia" (Shulman, 1987, p. 11). Although rounds of educational reform have, to some degree, built upon knowledge that was gained in previous rounds,[1] knowledge that could be immediately useful for improving teaching on a lesson-by-lesson basis often continues to be siloed in individual classrooms with individual teachers. Most teachers "have learned from each other only in the most haphazard way" (Hiebert, Gallimore, & Stigler, 2002, p. 11) and essentially start anew when they begin teaching. Teachers have no easy way of standing on the shoulders of those who have gone before them.

In this second editorial in our 2020 series on overarching problems in mathematics education, we discuss the possibilities of retaining and sharing professional knowledge as a way of addressing the problem of always starting over. We see this as the second of five overarching problems in mathematics education that we believe must be addressed for the field to make significant progress on improving teaching and learning. Specifically, we take up three aspects of this problem: (1) describing the nature of professional knowledge that, if preserved and shared, would be useful to teachers; (2) identifying obstacles (in many countries, and

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[1] One example can be seen in tracing the development of mathematics standards documents from the 1989 National Council of Teachers of Mathematics (NCTM) Standards through the Common Core (National Governors Association Center for Best Practices & Council of Chief State School Officers, 2010) era.

particularly in the United States) that can prevent this from happening; and (3) proposing some ways in which this professional knowledge can actually be shared and improved over time. For each aspect, we identify research questions that the field can investigate empirically.

Lesson-Level Professional Knowledge for Teaching

The construct of teacher knowledge or knowledge for teaching has a long and rich history in educational research, and there have been many characterizations and categorizations of this knowledge. Over 30 years ago, Lee Shulman (1987) proposed seven categories of teacher knowledge: subject-matter content knowledge; general pedagogical knowledge; curriculum knowledge; pedagogical content knowledge; knowledge of learners and their characteristics; knowledge of educational contexts; and knowledge of "educational ends, purposes, and values, and their philosophical and historical grounds" (p. 8). These categories, particularly subject-matter content knowledge, pedagogical knowledge, and pedagogical content knowledge, have been of great interest to mathematics education researchers as they have attempted to map the terrain of mathematics teachers' knowledge (e.g., Ball & Bass, 2000; Carpenter, Fennema, & Franke, 1996; Wilson & Berne, 1999).

Twenty years after Shulman proposed the construct of pedagogical content knowledge, Hill, Ball, and Schilling (2008) noted that the field still needed a more detailed understanding of that knowledge. Since then, teams of mathematics education researchers have worked to better specify and measure the content knowledge and pedagogical content knowledge of mathematics education. For example, Hill et al. (2008) proposed a model of Mathematical Knowledge for Teaching (MKT) that includes several aspects of both subject-matter knowledge and pedagogical content knowledge. Their work focused on elementary and middle-grades mathematics teaching, but other groups have extended the concepts to mathematics instruction at the secondary level, including geometry (e.g., Herbst & Kosko, 2014; Mohr-Schroeder, Ronau, Peters, Lee, & Bush, 2017) and algebra (e.g., McCrory, Floden, Ferrini-Mundy, Reckase, & Senk, 2012). Internationally, there has also been large-scale work characterizing high school teachers' MKT (e.g., Krauss, Baumert, & Blum, 2008) as well as math teachers' general pedagogical knowledge (e.g., Döhrmann, Kaiser, & Blömeke, 2012; Tatto et al., 2012), which includes knowledge like classroom management techniques.

Even with this large body of research investigating teacher knowledge, there is still more work to do. The field needs to address a continuing debate about what kind of knowledge is most useful for teachers when they are in the midst of planning, enacting, and revising lessons for instruction.[2] In addition, the field could benefit from precise descriptions of aspects of this knowledge that can be preserved, shared, and gradually improved over time.

We propose that researchers supplement the agenda on knowledge for teaching by seeking to describe this knowledge at a smaller grain size—the level of an

[2] In the field of professional knowledge and expertise, there is considerable debate between fluency models, which are about reflective practice, and other models that centralize a disciplinary knowledge base more explicitly (Kotzee, 2014).

individual lesson or instructional task or learning opportunity embedded in classroom practice. Because the tasks chosen and the learning opportunities created by teachers set parameters on what students can learn (Jacobs & Spangler, 2017; Stigler & Hiebert, 2017), we encourage researchers to study the nature of knowledge that teachers need to create ambitious learning opportunities for their students. What kinds of knowledge are most useful for teachers who want to design specific learning opportunities within specific lessons that help their students learn richer and more important mathematics? Examples of these kinds of lesson-level knowledge might include understanding how the mathematics of a specific learning opportunity fits within the lesson and within the larger curricular sequence, recognizing how the prior knowledge students bring with them could connect with the new ideas in a particular learning opportunity, recognizing the ways in which student learning in a lesson will connect with later learning, predicting the responses students will give to a particular task, planning the sequence in which students' responses would most productively be discussed, and knowing the important questions to ask at particular moments of a lesson. Because this knowledge is tied to particular lessons and learning opportunities, it is very specific. It could be at the level of knowing that a task for these particular seventh graders on graphing linear functions is more productive at a certain point in the lesson if the task uses $f(x) = 2x + 5$ instead of $f(x) = x - 3$. Or it could be knowing that these particular first graders need more experience finding solutions using counting-all strategies before introducing a problem that suggests a counting-on strategy.

We believe that the knowledge that contributes to designing ambitious learning opportunities, and that is often developed by studying students' responses to these learning opportunities, is a kind of professional knowledge analogous to the knowledge developed in other professions to improve daily practice (Kenney, 2008; Langley et al., 2009). This knowledge emerges as practitioners propose and test small changes in their daily work. It is the knowledge that can be preserved, accumulated, and shared so that others can use it, and it is the knowledge that enables novice practitioners to build on the knowledge of their predecessors. This knowledge is the antidote to a profession's "collective amnesia" (Shulman, 1987, p. 11).

We conjecture that professional knowledge of this type will have similarities and differences with the knowledge for teaching that has received most attention in mathematics education. It surely will have important connections with pedagogical content knowledge and MKT. However, this kind of knowledge—a form of knowledge-in-practice and knowledge-of-practice (Cochran-Smith & Lytle, 1999)—is unlikely to reflect theoretical distinctions that come from researchers' perspectives. Rather, in the vein of the *practitioner knowledge* described by Hiebert, Gallimore, and Stigler (2002) or the *theory-enriched practical knowledge* described by Oonk, Verloop, and Gravemeijer (2015), it is likely to be linked with practice, integrated, detailed, concrete, and specific.

To conduct research on the professional knowledge that can be accumulated over time and can be used by teachers to improve their daily practice, the field will need to conceptualize this knowledge in ways that help observers know when they see it in action and help researchers know how to assess it. The kind of knowledge we have in mind is qualitatively different from many other forms of professional expertise that are commonly assessed publicly (e.g., in the performance of professional athletes or musicians). Questions that could guide research on the nature of this knowledge include the following: What are indicators of this knowledge when it is being actively exhibited? How can this kind of knowledge be made transparent and how can it be preserved and copied, especially if it is embedded and actualized in practice? What kinds of patterns can be detected in the similarities of knowledge used across teachers and classrooms? What grain size is most useful for describing this knowledge? How is this knowledge connected to other kinds of knowledge that cross over lesson boundaries, such as knowledge of social and sociomathematical norms? What kinds of professional knowledge can be made public, accumulated, and used by others, and what kinds can only be developed by each teacher individually, through personal practice and experience?

Obstacles to Building Lesson-Level Professional Knowledge for Teaching

As an extension of the research on pedagogical content knowledge and MKT, we believe the field could benefit from increasing its attention to task- and lesson-level professional knowledge of the type described above. We also believe that there are a number of obstacles that must be managed for research to move forward on the nature and use of this knowledge. We begin this section by identifying one major obstacle: the devaluation of this kind of knowledge by many educators, including researchers, policy makers, and practitioners.

The Devaluation of Lesson-Level Knowledge for Teaching

Because the knowledge and expertise that one teacher gains in his or her classroom have not typically been seen as valuable, there is no cultural expectation to preserve and share it.[3] We consider two factors that we believe contribute to this devaluation. We argue that both factors represent a limited vision of this type of knowledge, and we include possible research questions that could help the field better understand these factors and how to deal with them.

The challenge of generalizing lesson-level knowledge. Mathematics education researchers' concerns about generality and significance contribute to the devaluing of professional knowledge that is tied to particular lessons and tasks in specific contexts. Knowledge that is limited to individual lessons and difficult to generalize across contexts is considered of lesser value by researchers, who are understandably incentivized to value broad significance in their research findings. After all, as we have argued in previous editorials, significance is a critical concern when envisioning and conducting research and disseminating findings (Cai et al., 2019). Publishing findings in a research journal, for example, requires that a researcher creates an argument about the contribution of the work that justifies its significance.

[3] Some of this knowledge is, in principle, not storable, and some is tacit and thus hard to express effectively. Here, we focus on the empirical question of what may be stored and shared in ways that are helpful for improving teaching.

We believe, however, that a strong argument can be made for the value of professional knowledge that is situated in particular lessons in particular classrooms. For example, as teacher–researcher partnerships work to solve specific instructional problems that are shared by multiple teachers, over time, their work tends to reach sufficient scope to be relevant and significant beyond one local context. The findings might show, for instance, that tasks of particular kinds create productive learning opportunities for students with some profiles but not others. Moreover, this kind of work goes beyond blind trial and error; it can be guided by hypotheses that are both grounded in existing knowledge and oriented toward explaining why a solution works. However, there is much to learn about how to design, conduct, and report on research of this kind. We take up this challenge in a later section.

Changes in learning goals and curricula. A second reason that lesson-level professional knowledge for teaching is devalued is that knowledge tied to individual lessons or tasks in specific curriculum materials is too ephemeral to be of value. States, districts, and schools in the United States frequently change their learning goals for students and change the curriculum to align better with these goals. Changes in learning goals are made for various reasons, including the use of new assessments that cover different topics and to meet changing policy mandates (e.g., adopting new curricula that explicitly claim to be based on the latest set of standards). If professional knowledge is tied to specific lessons, what value can there be when the lessons change every few years? Why would one build, share, and continuously improve a knowledge base when the lesson on which it is based might be gone in a few years? The United States, with thousands of school districts using a wide variety of ever-changing curriculum materials, provides something of a worst-case scenario of this concern.

We believe that frequent changes in learning goals and curricula are not only a reason for devaluing the knowledge that teachers develop about implementing particular lessons but also a symptom of this devaluation. The fact that frequent changes are made in curricula signals that little value is attached to the knowledge that teachers develop. All too often, colleagues from other countries express surprise at how frequently curricula change in the United States. In their countries, curricula could not change that often because it takes many years for teachers to learn to teach a curriculum well. Teachers would have "whiplash," they say, if learning goals and curricula changed that often. Clearly, greater value is attached to teachers' lesson-level professional knowledge in those countries.

Because mathematics education researchers rarely have control over wholesale changes in curricula, it would be useful to better understand which aspects of lesson-level professional knowledge can be preserved across curriculum changes. Looking at the problem from the other direction, researchers might ask whether there is a way to change curricula that would allow this knowledge to be preserved. This implies a need to reconceptualize what good curriculum change means. Could curriculum change be transformed into a positive driver for professional knowledge rather than a cause to abandon it? Curriculum itself has long been considered potentially educative for teachers (Ball & Cohen, 1996; Davis & Krajcik, 2005). Educative curricula can help teachers develop their subject-matter content knowledge as well as their pedagogical and pedagogical content knowledge (Lloyd, Cai, & Tarr, 2017). Davis and Krajcik (2005) outlined a set of high-level guidelines and design heuristics for educative science curricula that include the goal of promoting teachers' pedagogical design capacity—their ability to harness and adapt curriculum materials to achieve their instructional goals. Could innovative curriculum materials be designed in such a way that they would encourage teachers to incorporate their lesson-level professional knowledge developed while implementing another curriculum? Could this knowledge be used to implement the new curriculum more effectively? Can knowledge developed by teachers through applying their pedagogical design capacity be shared both with other teachers who are using those materials and with curriculum developers who could use that knowledge to inform revisions?

The Challenge of Conducting Research on Lesson-Level Knowledge for Teaching

As we noted earlier, one reason for devaluing lesson-level knowledge for teaching is the challenge of generalizing findings about one lesson in one classroom to other lessons and other classrooms. We see the generalization of findings from local settings as part of a larger problem in the mathematics education research landscape. Our field has made considerable progress in developing research designs and analytical techniques that optimize the possibility of generalizing findings from a sample to a target population. These designs are suitable for investigating research questions that allow separating main effects from contextual factors that could mediate these effects. More recently, researchers have developed ways of interpreting the generalizability of case studies and of describing what generalizability can mean in these designs. Comparatively little work has been done on research designs appropriate for investigating generalizability of lesson-level knowledge for teaching.

Research questions related to this challenge are about the research process itself. As in the first editorial in this series (Cai et al., 2020), we believe the field could benefit from a better understanding of how to conduct research to address the major problem we pose. What kinds of designs and analyses could reveal the kinds of lesson-level knowledge that can be preserved and shared? What research methods can tease out the conditions that influence the knowledge teachers develop while teaching (e.g., during planning, implementing, and reflecting)? How can patterns be detected in useful lesson-level knowledge across contexts? How should generalization be interpreted in this context?

Sharing and Improving Lesson-Level Professional Knowledge for Teaching

As we noted earlier, it is likely that not all lesson-level knowledge for teaching can be represented in a way that allows it to be preserved and shared. Some knowledge for designing and implementing lessons and for creating learning opportunities for students is likely to be personal, implicit knowledge. However, we argue that some of this knowledge, perhaps more than usually presumed, can be made explicit and public. This is knowledge that can be represented in ways that allow it to be preserved, shared, and accumulated. It is knowledge that can form a growing knowledge base for teaching with increasing effectiveness toward specific learning goals through using specific learning opportunities.

How can professional knowledge at the level of tasks and lessons be shared in ways that grow and improve the knowledge base over time so that it is most useful for improving teaching? Teachers in many countries enter the classroom within a system that lacks a well-established, organized mechanism through which they can learn from the best of what the teacher next door has been doing for years or from what the previous teacher in their classroom learned over a lifelong career. Indeed, in a number of countries, practicing teachers are socialized into an existing system in which each teacher largely operates in isolation (Lortie, 1975).[4] Although teacher collaboration is more of a norm in some countries, it is not necessarily the norm even in countries with national curricula. Alternatives to the siloed system have been proposed and widely discussed (e.g., lesson study and professional learning communities), but their sustainability and longevity as effective mechanisms for professional learning and knowledge development in a system that is traditionally highly individualistic remain a topic of research (Hairon, Goh, Chua, & Wang, 2017; Lewis, Perry, & Murata, 2006). How, then, can the wisdom of teachers that Dewey talked about be developed, even if that wisdom is a challenging concept for the empirical researcher?

These observations lead us to ask the following questions: How can teachers, both preservice and practicing, prepare to create, function within, and sustain a system in which usable professional knowledge is developed and shared by those in the profession? How could this knowledge accumulate over time while remaining accessible and easily usable by teachers who are teaching toward the same learning goals and are planning to use that task or teach that lesson? What infrastructure would be most helpful to teachers to support this work? Given that teachers already have many demands placed on their time and energy, there must be policy and structural changes that will create space and time for the development and sharing of lesson-level professional knowledge. But this, too, creates open questions. What policy and structural changes will be most effective to support teachers' participation in a system of professional knowledge acquisition and sharing? What kinds of supports will teachers need to successfully learn from each other? The research community must bear some responsibility for making this leap, in advocating for changes in teachers' work lives that enable developing and improving lesson-level knowledge, in collaborating with teachers to create effective structures and mechanisms to study the classroom interactions that generate this knowledge, and in building a professional knowledge base that accumulates and makes accessible this knowledge. What are the critical components of a productive and sustainable collaboration for doing this work? How do current resources, including time, curriculum materials, professional development opportunities, researcher and practitioner journals, face-to-face and online communities and forums, and professional incentives, fail to preserve lesson-level professional knowledge in a way that teachers can easily use to improve teaching? What are the most effective roles for researchers and teachers for generating and

[4] That said, there is ample evidence of informal systems through which new teachers are enculturated into the culture of schools, often negating the effects of teacher preparation programs as new teachers encounter "practice shock" (Korthagen, 2010, p. 98).

continuously improving this knowledge base? In other words, what path will future research need to follow to produce a lesson-level professional knowledge base that grows and improves over time?

Conclusions

In this editorial, we posed the problem of constantly starting over, of every new teacher beginning from scratch on their own rather than taking advantage of what thousands of colleagues have learned over time about how to teach effectively toward the same learning goals. Ultimately, the mathematics education community must address this problem if there is ever to be long-term, lasting improvement in educational practice. We have posed a host of research questions about the nature of the lesson-level professional knowledge that teachers need to create specific learning opportunities for students, about the obstacles that have prevented this knowledge from being valued and subjected to study and improvement, and about representations that would enable this knowledge to be made explicit and public as well as structures and mechanisms that would allow this knowledge to be preserved, shared, and improved over time. We hope that these questions will stimulate the work of the community to identify, value, and share the kinds of professional knowledge for teaching that will accumulate over time to improve the teaching and learning of mathematics.

In the next editorial, we explore an extension of this problem. As the third major research problem in our series, we pose the following problem: Innovative solutions in education too often remain local. This problem, sometimes characterized as a "scale-up" problem, is often a major barrier to improving teaching and learning on a wide scale (Cobb, Jackson, & Sharpe, 2017). It is not enough to simply share professional knowledge across different locations because the knowledge that is shared with teachers in a new context may not apply (or may apply differently) in that context. The next hurdle, then, is to better understand how professional knowledge and educational interventions work across contexts. Thus, from the perspective that we have laid out in this editorial, the next problem is how to scale up lesson-level knowledge generated in one setting to multiple different settings.

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