TEACHERS OFTEN LACK ACCESS TO QUALITY STEM PROFESSIONAL DEVELOPMENT.

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CONTEXT AND TRENDS

Efforts to improve K–12 science, technology, engineering, and mathematics (STEM) education will necessarily require quality teachers in the classroom, due to the significant effect teachers have on student learning (Rivkin, Hanushek, & Kain, 2005). Policymakers advocate for the use of large-scale teacher professional development (PD) as one way to improve lagging student outcomes in STEM (National Council of Teachers of Mathematics, 2014; Wilson, 2013).

Professional development is particularly vital for teachers responsible for STEM instruction for several reasons. First, teachers do not enter the workforce as experts in teaching. Teacher preparation programs intend to instill key content knowledge and pedagogical skills teachers need to begin their careers. However, policymakers and researchers have questioned whether the quality of such programs is sufficient (National Research Council, 2010). In particular, many teachers start their careers lacking basic knowledge of the STEM content they are being asked to teach to students, particularly at the elementary level (Tatto et al., 2012). Indeed, studies show that STEM-specific teacher preparation for the elementary grades is often insufficient (Cannata & McCrory, 2007; McCrory & Cannata, 2011; Wilson, 2011).

Regardless of the quality of teacher preparation, teachers need access to ongoing learning and support to ensure the content and skills they are teaching are most consistent with what is currently known and being practiced in the field. Advances in scientific knowledge and technological innovations are moving at a rapid clip in today's world, changing the types of knowledge and skills students need to thrive in and outside of the classroom and the types of learning experiences that provide them. Therefore, even teachers with strong content backgrounds in the STEM disciplines will need continued opportunities throughout their careers to deepen their understanding of STEM ideas and core concepts.

Despite this great need for enhanced and more frequent teacher PD in STEM, teachers across the K–12 continuum often lack access to the types of high-quality PD experiences focused on STEM teaching (Banilower et al., 2013).

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DISCUSSION

Teacher professional development encompasses many different goals, including developing teacher content knowledge, familiarizing teachers with new curriculums, or introducing teachers to new pedagogical strategies. PD can also encompass a wide range of activities, including coaching, mentoring, professional learning communities, workshops during the school year, and summer institutes. Within this diversity of PD experiences, general characteristics of effective PD have been identified: (i) a focus on specific content; (ii) opportunities for active learning; (iii) coherence with other policy and practice; (iv) collective participation of teachers from the same school, grade, or subject; and (v) sufficient duration (Desimone, 2009; Desimone, 2011; Desimone, Porter, Garet, Yoon, & Birman, 2002; Garet, Porter, Desimone, Birman, & Yoon, 2001). In STEM PD in particular, closely tying the activities to practice, such as using student work, teaching videos, or other artifacts from classrooms, is also considered an important characteristic of effective PD (Ball & Cohen, 1999; Lampert, 2009; Penuel, Fishman, Yamaguchi, & Gallagher, 2007).

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However, most teachers lack access to PD that possess these characteristics. In particular, much of the PD in which teachers participate is not specific to the teaching of STEM subjects, and instead focuses on domain-general aspects of teaching (Wilson, 2013). For example, in a nationally representative study of teachers responsible for mathematics and science instruction (Banilower et al., 2013), 77 percent of elementary, 54 percent of middle school, and 43 percent of high school science teachers reported spending less than 15 hours in the last three years on science-focused PD. Likewise, 70 percent of elementary, 46 percent of middle school, and 47 percent of high school teachers report spending less than 15 hours in the last three years on mathematics-focused PD. Furthermore, this national survey found that fewer than 44 percent of the teachers reported attending PD in the last three years that included examining artifacts from the classroom, highlighting another missing element of high-quality PD for teachers responsible for science and mathematics instruction. These data indicate that teachers are spending relatively little time in STEM-specific PD overall and for any significant duration, let alone PD that is consistent with what is considered as best practices.

Many researchers suggest that this lack of widespread access to high-quality STEM PD is caused by difficulties in implementing high-quality PD programs that have been shown to be effective on a small scale with large groups of teachers (e.g., Heck, Weiss, & Pasley, 2011; Marrongelle, Sztajn, & Smith, 2013). As district staff or school administrators often decide which PD programs are used, districts need the capacity to identify and support high-quality STEM PD (Cobb & Smith, 2008). One challenge that districts face is the lack of a consistent framework for understanding and judging the quality of PD (Desimone, 2009). Additionally, few studies have been conducted on particular PD programs to demonstrate their effectiveness (Borko, 2004; Desimone, 2009; Heck et al., 2011). Therefore, teachers, school staff and district staff, as well as policymakers, are left with little guidance as to how to ensure the quality of PD programs, making it likely that programs with little effect on teachers and students may be selected. Another challenge districts face is access to skilled facilitators to lead PD sessions. Although the education community's understanding of effective STEM PD facilitation has been improving (e.g., Borko, Koellner, & Jacobs, 2014; Elliott et al., 2009), these skills are often underdeveloped in instructional leaders in schools and districts who often lead STEM PD.

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BRIGHT SPOTS

Although much more work is needed to identify effective professional development models that support STEM teaching and to understand the conditions that can sustain this type of PD at a large scale, some promising examples exist. For example, the *Science Teachers Learning Through Lesson Analysis* (STeLLA) PD program centers on analyzing video cases using two complementary lenses: (1) student thinking and (2) science content storyline. This PD model has shown effectiveness with fourth- through sixth-grade teachers in developing teacher content knowledge and improving student learning as compared to PD that focuses only on developing teachers' content knowledge (Roth et al., 2011). In mathematics, the lesson study model of PD, with additional mathematics resources, has been shown to produce positive gains in student and teacher outcomes compared to teachers engaged in typical PD for elementary teachers (Perry & Lewis, 2011; Lewis & Perry, 2015). In this type of PD, small groups of teachers collaboratively plan, observe, and analyze a common lesson, focusing on understanding the way the lesson influences students' mathematical thinking. Additionally, further efforts are being taken to look at the effectiveness of lesson study across multiple large school districts (Takahashi & McDougal, 2016).

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In terms of developing capacity at a district level, the *Middle-School Mathematics and the Institutional Setting of Teaching* (MIST) research project has iteratively revised a detailed theory of action that outline the necessary components of a district's system for supporting instructional improvement in mathematics. This theory of action has been tested in several districts (Cobb & Jackson, 2011). For example, MIST's work suggests that district instructional leaders, including those who lead PD, need to understand improvement of instructional practice as a developmental trajectory rather than as fixing deficits in teachers' current instructional practice (Jackson et al., 2015). Additionally, the project found that PD leaders were able to develop this capacity by examining video of previous PD sessions they facilitated and jointly planning and rehearsing sessions for upcoming PD sessions with accomplished STEM PD facilitators.

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CONCLUSION

In today's rapidly changing, STEM-driven world, all teachers would benefit from more access to STEM-specific PD programs that are ongoing and of sufficient duration. Teachers need (and deserve) to be well-positioned to provide the most relevant, up-to-date, and engaging STEM instruction to their students. In addition, STEM PD could be strengthened by an increased use of classroom artifacts that ground the PD in the practice of teaching and student learning. For these improvements to be made at a large scale, instructional leaders at either the school or district levels will need to be trained and supported to build local capacity to identify and facilitate PD that is effectively situated within their local contexts to meet teacher needs.

ABOUT THE GRAND CHALLENGES WHITE PAPERS

In 2017, 100Kin10 released an unprecedented representation of the big, systemic challenges to preparing and supporting STEM teachers following over two years of extensive research alongside more than 1,500 STEM teachers and hundreds of other education experts. As a part of this work, 100Kin10 commissioned a series of short white papers from well-versed thinkers and practice-oriented researchers to synthesize the most relevant research around the specific challenge areas. Together, they compose a thoughtful and well-rounded examination of the systemic challenges currently facing STEM teaching.

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