PROFESSIONAL DEVELOPMENT IS OFTEN TREATED AS A COMPLIANCE ISSUE.

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CONTEXT AND TRENDS

Recent reports from such organizations as the National Research Council and the National Academy of Science highlight concerns regarding the skills of teachers in science, technology, engineering, and mathematics (STEM; Singer, Ross, & Jackson-Lee, 2016). At the same time, questions remain about what the essential knowledge and skills are that teachers need to be adequately prepared to teach these subjects. Shulman (1987), who is often cited in discussions of teacher competence, proposes that beyond content knowledge and specific teacher behaviors in the classroom, teachers also need pedagogical content knowledge; specifically, they need preparation focused on "the blending of content and pedagogy into an understanding of how particular topics, problems, or issues are organized, represented, and adapted to the diverse interests and abilities of learners, and presented for instruction" (p. 8).

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Teacher preparation programs and certification requirements are not often structured to develop this level of pedagogical content knowledge. Earning a degree in a specific content area, requiring a higher grade point average for entry into teacher preparation programs, or requiring passage of a test for certification do not necessarily ensure teachers will be prepared to effectively blend content and pedagogy and face head-on the challenges of teaching to diverse learners in the classroom. Almost two-thirds of teachers report that their preparation programs did not prepare them for the realities of teaching (U. S. Department of Education Press Office, 2016; the White House, Office of the Press Secretary, 2014).

Because content knowledge, pedagogical knowledge, and pedagogical content knowledge are rarely fully developed by teachers' preservice training programs, professional development is called upon as a means of remediation, tasked with covering the basic skills teachers lack, rather than as a tool of continuous improvement or enhanced professional growth.

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DISCUSSION

Professional development is often treated as an add-on or as another compliance mandate to be met by districts, schools, and teachers (Calvert, 2016). Many states have policies that require teachers to attend a specified number of days or hours of professional development either yearly or over a number of years to retain certification. Districts often include a set number of days of professional development in their yearly calendars for workshops. Such requirements for seat time confuse quantity of professional development with quality of professional learning opportunities, and have been found to be ineffective (Gulamhussein, 2013; Moon, 2013; Yoon, Duncan, Lee, Scarloss, & Shapely, 2007; Garet, Porter, Desimone, Birman, & Yoon, 2001).

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Forced to serve as the primary vehicle for building the knowledge and skills that teachers did not acquire prior to entering the profession or need to develop as practitioners, professional development often takes the form of one-size-fits-all workshops. Teachers describe this type of professional development as irrelevant, ineffective, and disconnected from their efforts to facilitate their own students' learning (Calvert, 2016). Little time or funding is available for job-embedded professional learning that is tailored to fit individual teachers' needs or to support teachers' reflection on their practice, collaboration with other teachers, or consultation with content experts such as engineers and other scientists.

Moving beyond professional development as remediation to a more job-embedded and customized approach to teacher professional growth requires using existing professional learning tactics that have worked well, in addition to adopting new models. Teachers report that learning from other teachers and observing other teachers are characteristics that make professional learning most valuable (Zhang, Parker, Koehler, & Eberhardt, 2015). One tool for providing an opportunity for such valued experiences is mentoring. Mentoring programs can support new teachers as they are inducted into the profession, but also can go beyond the transfer of knowledge and skills from an experienced teacher to a beginning teacher. Mentors also may serve as coaches, counselors, and sponsors (Matlach & Poda, 2016). Mentoring can lead to a mutually beneficial partnership of professional learning (Zembytska, 2016) in which mentors and mentees work together to foster continuous improvement for both teachers.

A less-utilized model in the teacher support space is the externship. Used in other professional fields such as law and medicine, externships provide the opportunity for novices to work

alongside expert practitioners. In medicine, nursing externships are seen as ways to ease the transition from the classroom into clinical practice, help hospitals recruit employees that need less time for orientation, and build the self-confidence and knowledge of new nurses (Ruth-Sahd, Beck, & McCall, 2010). One can easily see the parallel for teacher induction programs.

For STEM teachers, externships go beyond new teachers working with veteran teachers. Externships also include novice and more experienced teachers working alongside technicians, engineers, and scientists as those industry professionals conduct their own work. Teachers may spend time in a workplace outside the classroom during the summer and engage in problem-based projects throughout the school year, supported by their externship hosts. Other externships may include a professional learning experience led by a scientist or subject matter expert during the summer or in sessions across the school year that are facilitated by an education specialist. Experiences like these help to build teachers' pedagogical content knowledge, particularly in the rapidly changing STEM fields, as they can better understand the connections between topics, problems, or issues and how they are best presented to students through their own experiences as learners.

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BRIGHT SPOTS

Teacher preparation: To reduce the need for remedial professional development, some teacher preparation programs are working to take a different approach in order to better provide the content knowledge and skills teachers need before entering the profession. The Woodrow Wilson Teaching Fellows program is working with states and universities across the nation to develop a pipeline of STEM teachers ready for the challenges of a teaching career. Twenty-eight universities in Indiana, New Jersey, Ohio, Michigan, and Georgia are "partnering with local school systems, state government leaders, and community voices to redesign teacher education" (Levine, 2014). Another example is the UTeach program, which prepares STEM teachers for secondary classrooms. According to the UTeach website, 44 universities in 21 states and the District of Columbia are implementing this program. The program involves faculty with expertise in STEM fields, faculty with expertise in STEM teaching and learning, and master teachers who are considered clinical faculty. The aim of the program is to recruit undergraduate STEM majors and prepare them to become teachers.

Externships: Ignited connects educators with scientists, businesses, and industry through its programs including summer fellowships, Research Collaborative, Industry to Classroom workshops, and Tech Talks. These programs are designed to provide externships and other professional learning opportunities in solving problems and discussing issues in order to build a community focused on improving STEM education. In addition, according to the National Science Teachers Association (NSTA; 2012), programs like the Washington Alliance for Better Schools and the Northrop Grumman Foundation Teacher Fellowships offer three- to six-week-long opportunities for teachers during the summer to work in industry settings alongside engineers and contribute to challenging projects that "[inspire] the teacher to use her/his content knowledge and problem-solving skills to help the business solve a real challenge" (p. 8)

Maker Experiences: With the emergence of the maker movement, makerspaces (or hackerspaces) at schools, libraries, museums (such as the tinkering sessions at the Exploratorium in San Francisco, California), or other community locations provide the opportunity to

approach professional development in a new way and to infuse design thinking into the school curriculum. A makerspace "is a physical location where people gather to share resources and knowledge, work on projects, network, and build" (Educause, 2013). Rather than remediation for lack of content knowledge, makerspaces allow teachers to come together to employ and develop their knowledge of mathematics, science, and computer science, using the principles of engineering design in more playful and unintimidating spaces.

One example of maker experiences includes a group of teachers in Wisconsin who worked together to share their collective knowledge to design a learning opportunity they titled "Building an Electathon and a super-mileage car in a week" (Bessac, 2013). Professional learning can also occur at "maker meetups" or through providers like Maker Ed. Makerspaces include libraries and set aside spaces in school buildings for teachers to work collaboratively on self-directed design projects that can be incorporated into classroom practice. Materials can range from simple items (e.g., glass jars, yarn, milk cartons, wood scraps, and egg cartons) to more complex tools (e.g., welding equipment, lathes, and 3-D printers).

04 CONCLUSION

As teachers are significant contributors to student learning, they must have the requisite pedagogical, content, and pedagogical content knowledge to improve student interest and learning in STEM (Shulman, 1986). Stand-alone workshops that attempt to remediate the lack of knowledge or strategies teachers need are not sufficient. Personalized, ongoing, job-embedded, and collaborative professional learning experiences that begin as early as teachers' preservice years and continue throughout their career trajectories, such as externships, mentoring relationships, and engagement in problem-solving activities, are promising ways to prepare and sustain teachers as they face the classrooms of today and tomorrow and prepare students to take on the challenges and opportunities of the future.

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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