MANY TEACHERS LACK ACCESS TO QUALITY STEM CURRICULUM.

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01 CONTEXT AND TRENDS

In order to add 100,000 excellent science, technology, engineering, and mathematics (STEM) teachers to America's classrooms by 2021, our country must not only recruit and train but also retain these teachers. Addressing the revolving door of teacher turnover requires improving teacher working conditions, reducing job dissatisfaction, and better supporting teachers in their work (Ingersoll, 2001; Ingersoll & May, 2012). One of the working conditions that makes it harder to retain excellent STEM teachers is that they are often simply not provided with all of the tools they need to do their jobs. Specifically, teachers of STEM disciplines often lack access to high-quality STEM instructional resources and curricula that would facilitate successful teaching. In many cases, this leads to individual teachers developing tools from scratch, which in very few cases is the teacher's expertise and in most cases results in overworked, fatigued teachers.

The challenge of providing strong instructional resources to STEM teachers is more acute in disciplines such as technology and engineering than in science and mathematics. The Common Core State Standards (CCSS) and the Next Generation Science Standards (NGSS) now provide a foundation for mathematics and science curricula, and there has been deeper investment in the development of instructional resources in these subjects. However, researchers have raised skepticism about misalignment of even "Common Core–aligned" curriculum materials such as mathematics textbooks (Polikoff, 2015), and the NGSS remain largely under-adopted among states, with just 16 states officially signing on to use the standards as of February 2016. In contrast, agreed-upon standards and core ideas for engineering are less developed (National Academy of Engineering, 2010; Carr, Bennett, & Strobel, 2012), and in the technology discipline, a K–12 Computer Science Framework was released in 2016. Furthermore, supporting materials for the integration of engineering or technology core ideas into other subjects or in a multidisciplinary approach remain underdeveloped.

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DISCUSSION

Instructional resources are the tangible tools that support teachers' efforts to contribute to students' learning processes. They include, for example, curricula, lesson plans, textbooks, workbooks, trade books, manipulatives, structured experiments/explorations/demonstrations, interactive computer software, videos, and web-based content. Research on instructional design and cognitive psychology suggests that instructional resources can affect the extent of student learning by providing meaningful presentations of concepts, connecting concepts with prior knowledge and experience, engaging the interest of the learner, sequencing and organizing the opportunities for coverage and practice, differentiating instruction by providing multiple pathways to learning, and evaluating the degree to which learning occurs (Bransford, Brown, & Cocking, 1999).

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"High quality" means that use of these instructional resources, lessons, and curricula enables STEM teachers to generate better learning outcomes for their students. Teachers are often unsure of how to distinguish which instructional resources are high-quality, and districts often struggle to determine which engineering and technology curricula will be effective. There is too little rigorous research on the effects of instructional materials on student learning. In fact, although science and mathematics topics are addressed in the Institute of Education Sciences' What Works Clearinghouse, there are currently no review topics at all for technology and engineering. Research on the quality and effectiveness of curricula (e.g., Agodini, Harris, Thomas, Murphy, & Gallagher, 2010; Lalor, 2016; Reyes, Reys, Lapan, & Holliday, 2003) suggests that high-quality instructional resources can make a difference for student learning. The same research shows, however, that the effectiveness of a curriculum is largely dependent on the quality of a teacher's implementation of it, reaffirming the need to closely link curriculum with assessment, standards, and professional learning opportunities.

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Although countless STEM instructional resources are available online and many are free, often teachers are not aware of their existence, or how to find and assess those that are of high quality, or how to integrate those they identify into existing lessons, units and curricula.

Teacher access to high-quality STEM instructional materials is more than simply being able to open and retrieve a resource. In fact, at least six additional "A"s of access form a chain that is no stronger than its weakest link. Teachers must be (1) aware a resource exists. The amount of time to sift through the options, locate, and use the resource also must be (2) acceptable to teachers. Many teachers also need guidance to (3) accurately identify the resource as high quality. A teacher also needs to be willing and able to (4) afford the resource, and the resource must be (5) available for use in the classroom (e.g., there is time in the schedule, lab space and supplies, and adequate internet bandwidth) Lastly, teachers must be able to (6) appropriately integrate the resource into their instruction to meet the needs of their students (e.g., there are aligned standards, aligned assessments, appropriate adaptations for the level of students).[1] Specifically, recent research suggests that teachers turn away from online instructional resources because of the time required to filter through the large quantity of unranked search results, poor usability design of the materials they find, and concerns about the quality and accuracy of the resources (Carlson & Reidy, 2004; Collins & Halverson, 2009; Sumner, Khoo, Recker, & Marlino, 2003; Walker et al., 2011).

03 BRIGHT SPOTS

Several recent trends suggest positive developments in STEM instructional resources, including the rise of open educational resources (OER). Although it remains a challenge to sift through the offerings on the internet to locate those resources that are most likely to be effective, several groups curate lists of resources, including curricula and fully integrated programs that have been independently vetted for quality, such as Change the Equation's STEMWorks. Also, the National Science Digital Library serves as a valuable clearinghouse for high-quality STEM educational resources for teaching and learning (McArthur & Zia, 2008). Similarly, the National Science Foundation's (NSF) resources webpage provides a variety of full-service and special-purpose programs of curriculum material and instructional software generated by its investments in the development of STEM instructional resources. In addition, instructional resources that science teachers have recommended are available for free on the National Science Teachers Association's (NSTA) website.

There also is a growing recognition in the field that technology and engineering are strong potential platforms for STEM integration, and some programs are taking hold in schools and districts. Specifically, Project Lead the Way (PLTW) offers promising curricula for middle schools, such as Gateway to Technology, and at the high school level, Pathway to Engineering. Importantly, PLTW provides intensive professional development and ongoing support to teachers for application of those curricula.

In computer science and computing technology, there is an explosion of excitement around the Computer Science for All initiative and efforts to get all students to code. NSF has supported the development of an Exploring Computer Science course, and an AP Computer Science Principles course is now being used by thousands of teachers. CSforallteachers.org, funded by NSF, is a virtual community of practice for teachers, welcoming all PreK–12 educators to collaborate and share resources, experiences, and ideas for implementing computer science instruction into their classrooms. Code.org also offers free computer science course curricula for grades K–12 and is recognized as a leader in driving increased attention toward the importance of computer science learning.

[1] (Adapted liberally from Wyszewianski's commentary on a health care research framework of Penchansky and Thomas https://www.ncbi.nlm.nih.gov/pmc/articles/PMC1464050/)

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CONCLUSION

Teaching in STEM disciplines is challenging work. Ensuring that STEM teachers are equipped with the tools to do their jobs well makes that work a bit easier and is a key pathway toward recruiting and retaining excellent STEM teachers. There is a major opportunity with the rise of OER and a promising set of recent efforts to make more resources available to STEM teachers. If teachers are not supported in their efforts to separate the signal from the noise and identify the validated, effective instructional resources among all that are on the internet, however, an important opportunity may be missed.

- If you are a STEM teacher, check out the open educational resources and sites discussed above, evaluate them for yourself, share your own best materials, and become a coach or a guide to the best instructional resources for your local colleagues and teachers across the nation.
- If you are a researcher, work to evaluate and report the effectiveness of STEM instructional resources, particularly in engineering and technology. You can also advocate for the Institute of Education Sciences' What Works Clearinghouse to produce practice guides and include review topics for technology and engineering.
- If you are a champion of STEM, contact your networks via email or Twitter to make them aware of the bright spots mentioned here. You can join the movement to provide America's classrooms with 100,000 excellent STEM teachers by working with a 100Kin10 partner.

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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