



## **Recommendations to Realign the National STEM Education Agenda**

*Johannes Strobel, Nicole Weber, Melissa Dyehouse and Elizabeth Gajdzik, INSPIRE, Institute for P-12 Engineering Research and Learning, Purdue University*

President Barack Obama announced on his third day in office that increasing science, technology, engineering and math (STEM) literacy is a national priority.<sup>1</sup> Supporting STEM education in the pre-kindergarten to high school (P-12) sector is not new; yet international scoring cards such as the “Trends in International Mathematics and Science Study” report rank the United States unacceptably low.<sup>2</sup> Throughout the last few decades, reports from the National Science Board<sup>3</sup> and National Academy of Science/Engineering<sup>4</sup> repeat themselves with more questions than answers:

- How do we increase the interest of underrepresented minorities and female students in STEM?
- How do we attract, prepare and retain an adequate number of high-quality teachers in STEM subjects?
- How do we develop an infrastructure, awareness and cultural change toward making STEM education a national priority?

In the last few years, there have been several developments in STEM education that are noteworthy and provide some specific recommendations for actions. It is well understood in light of budget shortfalls and the existing zero-sum game that recommendations for actions mean other initiatives would receive less funding.

### **The earlier the better**

We are not focusing enough on the key age and grade levels for improving national STEM education. Most STEM education initiatives focus on the later levels of the P-12 spectrum,<sup>5</sup> in which career choices, not interest, is developed. While recent reports in the United Kingdom set the target age of STEM education at 11-14,<sup>6</sup> U.S.-based research indicates that elementary school is the critical juncture for maintaining student interest in science and is the point at which girls, in particular, turn away from science and math.<sup>7-9</sup> Girls are doing so as early as third and fourth grade and, for the ones persisting in STEM, the current climate within the STEM curricula produces a high level of anxiety and low self-efficacy.<sup>10</sup>



Furthermore, research indicates elementary-school teachers continue to teach science and math in isolation and grapple with barriers of insufficient content knowledge to better integrate disciplines, inadequate instructional time and limited access to or awareness of curriculum resources that blend disciplines.<sup>11</sup> This is even more pronounced in low socio-economical-status schools, a high percentage of which are not involved in any type of curriculum integration.<sup>12</sup> Focusing on STEM learning in elementary schools will provide the necessary foundation for students to consider STEM to be accessible, appealing and, ultimately, a viable future career path.

Several action items can be recommended:

- Provide more well-trained STEM teachers and caretakers in the early years of children's development and schooling.
- Focus on STEM education material for elementary classes, which in many cases means in the context of integrated curricula provided by a single teacher.
- More research on STEM learning progressions, especially in earlier grades.

### **Engineering integrated**

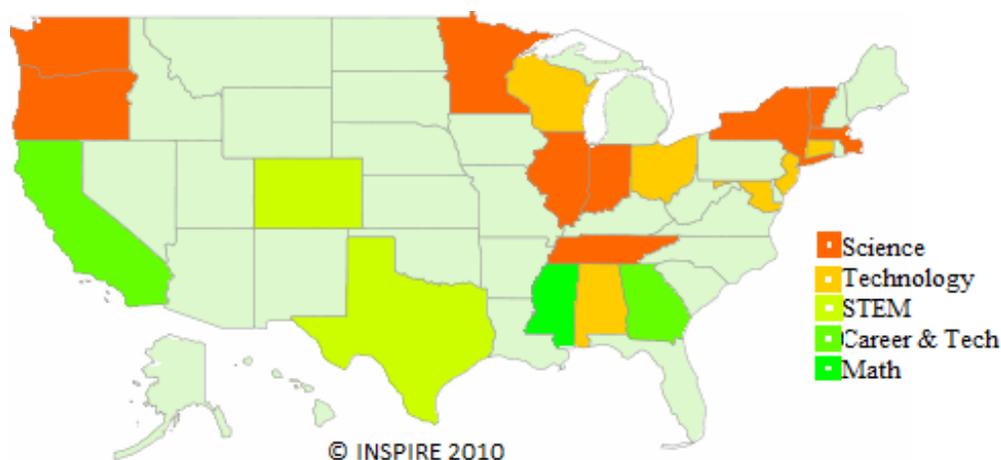
Engineering in the P-12 area emerges on the national stage as a viable agent of change to integrate STEM education. The “T” and the “E” in STEM are historically neglected in P-12 STEM education. While technology education continues to have a strong presence in grades 9-12, traditionally, engineering does not have a place in the U.S. elementary or middle-school curricula, neither in national standards nor in state or regional standards. As the book *Changing the Conversation* by the National Academy of Engineering points out, despite large efforts in outreach, K–12 teachers and students generally have a poor understanding of engineering and what engineers do.<sup>13</sup>

Engineering—defined here as an applied math and science, problem-solving and design discipline—is more strongly connected with the so-called academic disciplines of science and math. In the last few years, the amount of engineering curricula is dramatically increasing.<sup>14</sup> At the early grade-school level, instructional resources include *Engineering is Elementary* from the Boston Museum of Science and Technology,<sup>15</sup> which integrates engineering primarily with science, and *Model Eliciting Activities* developed at Purdue University and other institutions,<sup>16</sup> which integrates engineering with math. These are just two examples of material that aims to

increase the technological and STEM literacy of society. Due to their early grade orientation, the resources are focused on increasing interest, which later can lead to career choice.

Compared with science and math education, pre-college engineering is still in its infancy, yet recent developments provide tremendous support. In 2009, the U.S. National Academy of Engineering published a report on K-12 engineering education<sup>17</sup> and the academy just released an additional report on K-12 engineering standards.<sup>18</sup> Individual states took the initiative to integrate engineering into different curricula standards. Figure 1 provides a snapshot of the current implementation of engineering and the different curricula location in the United States.

**Figure 1: Engineering integration in individual states<sup>19</sup>**



While the verdict on the role of engineering in P-12 standards has yet to be spoken, several trends can be observed. For many P-12 engineering proponents, engineering standards are not intended to be stand-alone standards or to replace existing standards in the curricula. Engineering is meant to provide a context or vehicle to learn other academic disciplines while introducing integrative concepts and competencies, such as optimization, modeling, constraints, design, problem solving and critical thinking. The variety of different implementations demonstrates the wide concept of engineering, its role and the different stakeholders involved. Currently, we have to acknowledge that engineering as introduced at the pre-college level is diverging rather than converging.



Lastly, in many states, even those with engineering components, systematic plans for pre-service or in-service teacher training for engineering are lacking crucial details or do not exist at all. More research on the role of engineering is necessary, particularly in terms of engineering learning progressions. Additionally, teacher professional development in engineering models need to be developed, tested and scaled.

### **STEM and the social good**

STEM education and outreach activities are full of catapults, egg-throwing devices and technologies, which are used for the sake of technology. Research has shown there are three critical factors that motivate students to pursue a particular activity and, later, a career:

1. The experience is authentic, meaningful and connected to their own real-world understanding.<sup>20</sup>
2. Students believe in their competence in the activity. Some researchers have seen this to be important as early as elementary school<sup>21,22</sup> and others in middle school.<sup>23</sup>
3. The students' perceive the value of an activity, which predicts decisions about subjects and occupational path that the student continues to entertain.<sup>24, 25</sup>

Students are unlikely to continue with an activity if they find it uninteresting or too much of a time commitment. This has been identified as one of the strongest reasons for the relatively small number of women working in science, technology and engineering.<sup>26-28</sup> Furthermore, there is strong evidence that most women in the sciences are concentrated in disciplines related to helping others or improving the human condition<sup>29</sup> and that women tend to leave engineering for other majors, such as those perceived to be more likely contributors to social good.<sup>30</sup> *Changing the Conversation*<sup>31</sup> and the National Academy of Engineering's "Grand Challenges"<sup>32</sup> are going in the right direction.

Recommendations from research on the role of social good to interest and motivate students for STEM careers include:

- Focusing on instructional material, which portrays and embeds stronger references to the social good produced and sustained by STEM work and careers.
- Providing role models, which embody the social good components.

STEM education is a driving force for U.S. economic growth. Decades of investment and effort did not provide the desired results. This brief synthesizes three areas of new developments that could provide components to solutions.

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Johannes Strobel is the director of [INSPIRE, Institute for P-12 Engineering Research and Learning](http://INSPIRE.Purdue.edu) in the School of Engineering Education at Purdue University in West Lafayette, IN. He



*is also an assistant professor in engineering education and learning design and technology at Purdue. Strobel received his doctorate in information science and learning technologies from the University of Missouri in Columbia.*

*Nicole Weber is a post-doctoral research associate for INSPIRE. She received her doctorate in environmental biology with an emphasis in science education from the University of Massachusetts in Boston.*

*Melissa Dyehouse is a post-doctoral research associate for INSPIRE. She received her doctorate educational psychology from Purdue University.*

*Elizabeth Gajdzik is the research and policy associate for INSPIRE. She received her master's degree in mathematics education from Baylor University in Waco, TX.*