Science, Technology, Engineering, and Mathematics (STEM) Development: Pathways for Universities to Promote Success

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Abstract
The focus of this paper is on policies used in university communities to promote Science, Technology, Engineering, and Mathematics (STEM) development. The paper outlines how STEM can be expanded to engage stakeholders including colleges and universities, students and faculty, and academic and industry leaders. The paper emphasizes proven practices that engage and sustain educators and students in STEM experiences. Most needed to facilitate STEM efforts is a strong commitment from institutional leadership and clear measures to scale-up efforts throughout the campus. Key partners in this effort include university department heads, university deans, community leaders, business and industry leaders (e.g., Chamber of Commerce), departments of education, higher education committees, and the governor’s office. Successful STEM efforts attract multiple partners who collectively share risks and rewards of the STEM efforts.

Introduction
In recent years, there has been an increased focus on the critical importance of educating individuals in the fields of science, technology, engineering, and mathematics (STEM). This focus has resulted in wide-spread support and funding to develop and encourage numerous initiatives that place an emphasis on STEM. A variety of reports, including Rising Above the Gathering Storm (National Academy of Sciences, 2007) and Before It’s Too Late (National Commission on Mathematics and Science Teaching for the 21st Century, 2000), echo the purpose of a high quality mathematics and science education and its importance in preparing citizens for competition in a global society with STEM-based careers and professions. These reports emphasize the need for better preparation of K-20 teachers and students in all areas of STEM. To address this need, many STEM faculties in disciplinary departments at universities are working in collaboration with faculty in colleges of education. These partnerships are often formed in an effort to support mathematics and science teaching and learning in partnerships with school systems. Many of these partnerships are funded by outside agencies as a way to encourage the partnership and collaboration (for example, the National Science Foundation has funded these types of collaborations in the Math and Science Partnership Program throughout the United States). This paper outlines three proven strategies for engaging and sustaining STEM disciplinary faculty, College of Education faculty, and K-20 students in STEM experiences. These strategies will be outlined throughout the remainder of the paper and include: 1) Expanding the STEM pathway for student success, 2) Professional development and learning for partners in the STEM effort, and 3) Using technology to facilitate STEM efforts.

Expanding the STEM Pathway for Student Success

A STEM Pathway includes all of the experiences that students have from K-12 school to a career in a STEM-based field (for example, experiences in elementary school, middle school, high school, undergraduate education, internships, and graduate education). One of the first proven strategies for engaging and sustaining STEM disciplinary faculty, College of Education faculty, and K-20 students in STEM experiences in the STEM Pathway is to
develop structures on the university campus to increase student interest, participation, and achievement in STEM fields, especially among underrepresented students. Student diversity and a commitment to preparing all students must be a fundamental component of the work of our universities. It is imperative to engage faculty members who are experts in the science, mathematics, engineering and technology disciplines with students to provide experiences for the students that reveal the types of activities in which STEM faculty are engaged as part of their work. These scientists can also expose students to employers who work in the STEM fields to demonstrate how the college degree in STEM transfers into the world of work. Leadership for these experiences and structures that facilitate this type of interaction are provided by college and university presidents, provosts, and chancellors who have a vision for STEM education on their campuses. In order for the STEM pathways to be transformative and seamless, leadership should include federal agencies, STEM disciplinary societies, faculty and administrators employed in a wide variety of academic institutions, and employers in private industry.

One essential goal in expanding the STEM pathway should be on encouraging, recruiting, and mentoring students as they enroll in more rigorous mathematics, science, technology and engineering courses, both as high school students and when they matriculate to college as undergraduate students. However, attaining this goal is no small feat. First, university faculty who work with STEM students should agree that quality matters substantially more than quantity, and that a focal point should be on how STEM faculty teach rather than how much they teach. This is particularly true in the introductory science, mathematics, engineering and technology courses at the university where STEM students experience their first interaction with the activities of their future careers. These STEM courses must be well-connected and aligned to current issues and societal challenges so that students can easily recognize the application of the STEM content they are studying to real world problems. Indicators from STEM industries can be used to assist university faculty in this alignment and to emphasize the connections between bodies of knowledge and STEM work. It is also important to connect and integrate research and education and use research findings to drive and inform education. The best practices must be assembled and become tools and the knowledge basis for learning. This practice will improve the quality and productivity of undergraduate intellectual experiences. However, there seems to be de-emphasis on the importance of the STEM Pathway in some countries. For example, in the United States, federal support of basic research in engineering and physical sciences has experienced modest to no growth over the last thirty years. In fact, as a percentage of GDP, funding for physical science research has been in a thirty year decline. In contrast, at no time in history has the possession of knowledge been so strong an indicator of economic wealth.

In the midst of these economic constraints, one approach to strengthening the STEM Pathway depends on broad visions for collaboration among various stakeholders. These broad initiatives include the development of learning opportunities to improve undergraduate education and engage the university in wide reform approaches that analyze teaching and learning. Universities need to understand exemplary teaching and provide ample opportunities for colleagues to witness these practices so that faculty can transfer innovation from one department to another and one university to another. To do this will require the university to invest in building intellectual communities that share knowledge and synthesize shared data, thereby forging partnerships that stimulate research and teaching innovation on the university campus. Universities can then expand their partnerships to include business, industry, chambers of commerce, professional societies, National Science Foundation and
other funding sources. Ultimately, and probably the most difficult undertaking, is for universities to inform and encourage the public to understand how critical the STEM pathway enterprise is to their welfare.

**Professional Development and Learning for Partners in the STEM Effort**

A second strategy, that is absolutely necessary for engaging and sustaining STEM disciplinary faculty, College of Education faculty, and K-20 students in STEM experiences, is professional development and learning opportunities for each of the partners in the effort. For these opportunities to be institutionalized, the leadership of the institution must facilitate the development structure, put into place mechanisms for scaling up the number of STEM faculty participants, and sustaining the interdisciplinary STEM learning environments. One example of a leadership question to ask might be: How can STEM faculty be supported and rewarded for their work in STEM education? There are currently many more science, technology, engineering, and mathematics (STEM) faculty and other professionals working with school systems in partnerships to support mathematics and science teaching and learning as a result of funding incentives. One unique feature of some of these partnerships is that K-12 school teachers work together with mathematicians and scientists in the field. This type of interaction leads to collaborations between teachers and scientists doing field work and can result in improvements in teachers' classroom instruction. Researchers report that there are benefits for everyone involved, including teachers, scientists, and school students, in these types of STEM partnerships (Siegel, Mlynarczyk-Evans, Brenner, & Nielsen, 2005). For example, as a result of a teacher and scientist collaboration in a STEM partnership, there is teacher learning and scientist learning which then impacts the teacher's school classroom teaching and the scientist's university teaching (Canton, Brewer, & Brown, 2000; Dresner, 2002; Dresner & Starvel, 2004). Another outcome of these types of interactions is that research scientists and mathematicians who work with schools and teachers begin to better understand mathematics and science teaching in school systems and how their own work and expertise connects with school teaching and learning for students (McCombs, Ufnar, & Shepherd, 2007).

The poor rankings for students in the United States on measures of mathematics and science, when compared with their international peers, are one indicator that the need for STEM professional development at the K-20 levels is a growing concern. In *Rising above the Gathering Storm* (2007), the National Academies concluded that "the scientific and technological building blocks critical to our economic leadership are eroding at a time when many other nations are gathering strength." At the core of effective science teaching is "student-centered and inquiry-based opportunities for students to actively be engaged in learning." One of the most important ways to initiate institution-wide reform is to begin with an examination of the pedagogy being used to teach STEM courses at the K-20 levels. Institutions should ask important questions such as: Does this pedagogy meet the needs of 21st Century learners and of the STEM discipline and its careers? These critical examinations of pedagogy can spur the need for training and support as faculty adopt new cutting-edge pedagogies that meet the needs of learners and the discipline. Some changes will focus on intellectual communities and situated cognition that integrate new social interaction theories and new technologies that facilitate technologically advanced collaborations. The universities' colleges of education are likely experts in pedagogy and can assist in modeling some of these instructional innovations. Faculty from academic units across the university campus can also learn about diverse learning styles, ways to apply instructional technology to
sustain learning, and particularly how social media plays an important role in the current generation’s models for learning.

The preparation and development of teachers has come under fire and some leaders question the value and necessity of teacher preparation programs, implying that they do not take teacher education seriously. There are some very good teacher education models, yet many are expensive. Recently the Association of Public Land Grant Universities (APLU) designed an Analytical Framework for STEM Teacher Education to be used in the development and assessment of STEM teacher preparation programs. This framework describes an effective teacher preparation program for science and mathematics teachers, and provides some very specific examples of effective criteria and processes that should be used in teacher preparation programs. These criteria serve as a model and a guide for improving the preparation of STEM teachers. Once teachers are in the classroom it is important to continue their development as lifelong learners throughout their profession. But as reports show, career development for teachers in the United States is not systematic and cohesive, as it is in some other countries (Stigler & Hiebert, 1999). The National Staff Development Council’s (Wei, Darling-Hammond, Andree, Richardson, & Orphanos, 2009) report about professional development trends in education reported that teachers experience much less in-depth professional development and spend less time in professional development than they did four years ago. The decline in professional development, in a system where teachers are already lacking professional development opportunities in STEM, will have significant impacts in teachers’ instruction and student learning in STEM for years to come.

**Utilizing Technology to Facilitate STEM Efforts**

A third proven strategies for engaging and sustaining STEM disciplinary faculty, College of Education faculty, and K-20 students in STEM experiences is to use current technologies to enhance learning and interaction. Advancing technologies have minimized academic institutions as a depository of knowledge. Using knowledge networks is a much more vital and instrumental way of shaping new knowledge today, rather than having students recite what is already known. It is important for universities to identify the kinds of technology that are available and to remain current on those technologies to facilitate and engage more learner-centered teaching in STEM courses. Connecting with students in the K-12 STEM Pathway means that institutions should find ways to effectively use social and interactive asynchronous and synchronous media such as twitter, wikis, podcasts, e-books, blogs, social networking, gaming, videos, internet2, simulations, Second Life, or other interactive programs. These tools can be used effectively to promote student interest and achievement in STEM, in general education, and in STEM majors. One example could be the use of robots to teach students engineering principles and design. In fact, one Korean Education Policy is planning to use robots to teach thousands of kindergarteners by 2013.

Many universities are beginning to offer coursework and entire programs of study through the use of technology. While digital education is designed currently for adult learners, in time it is likely that the formats of on-line instruction will adapt to provide technological options for all levels of education and learners. These advances have the potential to make learning more individualized, interactive, and self-directed and could be used in a variety of STEM learning environments with students. For example, animal dissection using computer models has already replaced the dissection of real animals in many biology classrooms.
Both universities and public schools will need to keep current with the technologies that are already infused in students’ daily lives. Unfortunately rapid shifts toward the use of social media in society have not been followed by equally rapid shifts to these technologies by schools and universities. Institutions must become more agile in responding to technology changes so that the technologies students have learned to use in their daily lives can be applied to problem solving in their school and university experiences, particularly as those technologies apply to the solution of STEM problems. Unfortunately in many places, it is easy for students to see more technology at the gas station in their public school or university classrooms. An important way to change this trend it to ensure that instructors have opportunities to experience these technologies as part of their daily work so that they can integrate the technologies into their classrooms and interactions with students. Some college campuses were early adopters of podcast technologies, which provide their incoming students with tools to acclimate and navigate around campus. For these campuses it is common to see students walking around the campus with ear buds listening to campus map information, campus event information, or a STEM lecture for one of their classes. There are also public schools where students are using their IPod technology to listen to podcasts from their teacher or another source on topics such as the process of photosynthesis or the difference between equilateral and isosceles triangles. This technology individualizes learning and allows students to have anytime access to the STEM content they are studying in their courses.

Closing Thoughts

The purpose of this paper was to outline three proven strategies for engaging and sustaining STEM disciplinary faculty, College of Education faculty, and K-20 students in STEM experiences. These strategies focused on the importance of enhancing the STEM pathway for student success, the critical need for professional development and learning for partners in STEM efforts, and impact of new technologies on facilitating STEM efforts. Without the advances in knowledge and understanding that are brought about by study in STEM fields, our future generations will experience a great deficiency of understanding. In the book, *The Demon Haunted World*, Carl Sagan implies that this deficiency of understanding foreshadows an alarming future. He writes: “Finding the occasional straw of truth awash in a great ocean of confusion and bamboozle requires vigilance, dedication, and courage. But if we don’t practice these tough habits of thought ... we risk becoming a nation of suckers, a world of suckers, up for grabs by the next charlatan who saunters along.” Learning in the sciences, technology, engineering and mathematics are essential to the type of understanding that Sagan describes. Yet at many institutions of higher education only a small portion of the student undergraduate population completes a mathematics or science course after their freshman or sophomore year of college. This unfortunate pattern signals a lack of understanding about the importance and applicability of STEM to their daily lives and future careers and contributes to a citizenry that is less and less knowledgeable about science, technology, engineering and mathematics. The challenges of renewable energy, clean water, and global climate change will be the problems faced by the current generation of students studying STEM in K-20 education. Will this generation be less informed about science, technology, engineering and mathematics and make their state and national decisions based on what their Facebook friends value? Or can we count on this generation to use science, technology, engineering and mathematics to solve the world’s problems and advance STEM for the entire planet? Only an ongoing commitment to STEM pathways, instructional development, and integrated technologies will produce a favorable result for all.
References


