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Article · September 2012

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AMERICA'S CHILDREN: PROVIDING EARLY EXPOSURE TO STEM (SCIENCE, TECHNOLOGY, ENGINEERING AND MATH) INITIATIVES

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Recent attention has been brought to light in the United States regarding low numbers of students pursing STEM (Science, Technology, Engineering and Math) disciplines and degree programs (National Science Board, 2010). There is a great need in America for talented scientists and engineers. Numerous programs abound for high school and middle school students in regard to STEM initiatives; however, fewer opportunities exist for elementary students and their teachers. Research has shown that early exposure to STEM initiatives and activities positively impacts elementary students' perceptions and dispositions (Bagiati, Yoon, Evangelou, & Ngambeki, 2010; Bybee, & Fuchs, 2006). By capturing students' interest in STEM content at an earlier age, a proactive approach can ensure that students are on track through middle and high school to complete the needed coursework for adequate preparation to enter STEM degree programs at institutions of higher learning. As a result, programs focusing on STEM initiatives and content are a growing priority in American schools with aims to provide early exposure for elementary students.

Introduction

The face of the American economy and that of the global economy has seen increasing change over the past decade (National Science Board, 2010). The trend of these economies has increased in science, technology, and innovation, as well as become more knowledge intensive. The need for professionals in the fields of Science, Technology, Engineering, and Mathematics (STEM) continues to grow at a comparable rate as well to meet the demands of this high-tech global economy. The increase in professional workers in Science and Technology fields in the United States has seen steady growth over the past decade, but lags behind the dramatic growth of our European and Asian global competitors in developed countries (National Science Board, 2010). As a result, more focus has been placed on STEM initiatives in American schools. These initiatives have been largely seen in the middle and high school curricula, but there has been little change in the elementary curricula to support these growing trends. Bencze (2010) writes, "...although there is considerable academic and official curricular support for promoting student-directed, open-ended science inquiry and technological design projects in schools, the reality is that they rarely occur." (p. 58)

Review of the Literature

History

Current reform in science education and the push for STEM awareness by the Obama administration and nationally rec-

ognized foundations (e.g. American Association for the Advancement for Science, National Science Foundation) have emphasized projects and programs that encourage American youth to connect with STEM fields. Results on the PISA and TIMSS international studies of math and science exams have shown that American youth fall behind other developed countries in their abilities in science and math (Russell, Hancock & McCullogh, 2007; Russell, 1999)

In addition, various research studies of undergraduate student experiences in choosing STEM professions (Russell, Hancock & McCullogh, 2007; Russell, 1999) have noted that the best time to create a connection, awareness and interest in STEM fields would be the elementary years.

The number of students enrolling in more advanced math and science courses in high schools in America is on the increase according to the Federal Interagency Forum on Child and Family Statistics (2011). However, The National Science Board (2010) still projects a shortage of workers in the STEM fields in the United States in our near future. Over half of doctorate degrees in Natural Sciences and Engineering earned in the United States since 2006 were awarded to foreign nationals, largely from East Asia (National Science Board, 2010). Even though the number of undergraduate students entering STEM degree programs at four-year institutions has risen over the past decade, the rate of increase lags behind other developed countries.

Present Initiatives

One current initiative in promoting STEM in American education belongs to national organizations. The first is called *The Partnership for 21st Century Skills* (2004). The goal of this initiative is to prepare American children to develop the skills they will need in order to compete in our global economy. This partnership between educators, policy makers, and community members aims to provide tools and resources for public schools, and fight for policies that will advance the cause. The framework of this skill set encompasses reading, writing, arithmetic (3 R's), and other core subject areas; along with critical thinking and problem solving, communication, collaboration, and creativity (4 C's). 21st century themes, and information media and technology are also a focus of the partnership with support systems designating professional development for teachers and support for the learning environments. While some school districts were already embracing similar ideas, the partnership strives to provide equal support and resources for all schools across America at the local, state, and national levels. *The Partnership for 21st Century Skills* has recently become an important piece of the education system in America in its efforts to build readiness in American students as well as build collaborative partnerships among educators, business professionals, community members, and governmental leaders. This initiative is beginning to help build the skill set needed for American students to succeed in STEM disciplines as well as global competition.

Another current initiative in America is mandated by President Obama with his "Educate to Innovate" campaign (Whitehouse.gov, 2009). The goal of this campaign is to improve the performance and skills of American youth in STEM content through collaborative efforts of the federal government, leading companies, non-profit groups and educational societies. Together these forces are striving to improve education at all levels in STEM disciplines.

Early Exposure

As a result of the work of the *Partnership for 21st Century Skills* initiative and other important government and private agencies, the importance of providing earlier exposure to STEM initiatives for students in K-12 education has increasingly come to light for all educators. (Bagiati, Yoon, Evangelou, & Ngambeki, 2010; Bybee, & Fuchs, 2006). Engineering concepts, along with more advanced inquiry science and math concepts are being incorporated at much earlier stages of the elementary curriculum. It is the intention of these educators that by introducing elementary students to a science, math, and technology integrated curriculum, based on interactive problem-solving activities, interest in these types of STEM career fields will increase (Katehi, Pearson, & Feder, 2009). Swift and Watkins (2004) emphasize that "effective science and mathematics instruction must begin in the early grades." (p. 67) Elementary teachers need support to find ways to incorporate more hands-on, inquiry-based activities into the math and science curricula to assist in teaching the more abstract concepts. Swift and Watkins further stress that outreach programs, where engineers partner with educators to provide activities and instruction around engineering principles, have been effective.

The National Science Board (2010) reports a strong correlation between students who take advanced science and math courses in high school and their enrollment and success in four year college institutions. Likewise, there is also a strong correlation between high school students who do not take advanced courses typically do not enroll in four year college institutions, and those who do often need remedial support courses. This research supports the need for earlier exposure for elementary students to STEM initiatives. Early exposure may motivate students to enroll in more advanced science and math courses when they are available in middle and high school. This author is in the beginning stages of initializing such a research project.

Roth & Eijck (2010) conducted a study on lifelong learning in relation to science. They wrote that the focus in schools should be more on STEM processes rather than specific content in order to truly prepare students for the real world of science. In addition, Wood (2008) stated that what students are learning about science in American high schools from their teachers, textbooks, and the entertainment industry is keeping kids out of science, not promoting it. Science classes in schools need to promote more problem solving, critical thinking, and open-ended inquiry. These types of classroom activities develop process skills in students rather than simply learning content knowledge.

Although the amount of problem-based learning in science and technology classrooms has improved over the past decade, there is still room for growth and improvement in this area. Bencze (2010) writes,

> ...it also is apparent that many or most of these activities are, ultimately, teacher-guided to ensure students generate 'desirable' products. This is, apparently, part of a general movement in education to-in essence-*commodify* knowledge; that is, to tightly prescribe what is to be taught and learned and assessed and evaluated in discrete bundles. (p. 45)

Scientific problem-based activities promote critical scientific thinking and engage students in science. These kinds of lesson activities should not be reserved for middle school and high school classrooms. Elementary students have the cognitive abilities to engage in STEM content and problem solving activities which in turn will whet their appetites for more. Not only do STEM lessons and activities excite young learners, but they also build their confidence and self-efficacy in relation to their own abilities to be successful in more advanced math and science courses in later school years.

Impact on Elementary Teacher Education in STEM Disciplines

Teaching inquiry science is not a common approach used in elementary science classrooms today (Weiss, 2006). Many preservice teachers, upon completion of their teacher education programs, lack pedagogical expertise in scientific inquiry and technological design (Bencze, 2010). This is not only true for preservice teachers, but veteran teachers as well. They lack the self-efficacy to incorporate elementary scientific inquiry into their lessons. Ross (1998) reports that teachers with low self-efficacy to engage in inquiry based projects tend to refrain from using such a curriculum with their elementary students and they tend to have lower student achievement. This is true for elementary teachers who have less formal science education (Harlen & Holroyd, 1997).

The emphasis on standardized testing in America has hampered the growth of scientific pedagogy in the elementary schools to include inquiry-based projects. Elementary students often learn about scientific theory and the nature of science rather than doing scientific investigations for themselves. As a result, students are relying on the knowledge, products and conclusions of others rather than experiencing it for themselves.

When there is an emphasis on knowledge acquisition only with an increasing pressure to deliver a more structured science program in the schools, this can result in a negative impact on student motivation and expertise (Bencze, 2010). Students need to be allowed to construct their own knowledge and expertise through procedural and pedagogical methods that encourage and support inquiry. One way to approach this disconnect from theory into practice is for institutions of higher education to partner with elementary teachers to provide staff development on pedagogical inquiry-based learning and design as well as provide project-based STEM institutes for elementary students in order to gain exposure to STEM disciplines and content.

Current STEM Programs for Children

Universities around the country as well as public and private organizations are beginning to offer STEM initiative programs for K-12 students and their teachers. Many of these programs continue to focus on middle and high school students and often overlook elementary students (Vasquez, 2005; Yasar, Baker, Robinson-Kurpius, Krause, & Roberts, 2006). However, STEM programs focusing on elementary students are beginning to surface more and more. For instance, the University of Virginia's Children's Engineering Educators organization has had a positive impact on science education in the state of Virginia over the past several years through offering in-service for elementary teachers on engineering design concepts. Their focus has been on linking the children's engineering design concepts in their teacher preparation programs with existing school curricula, and through hosting summer camps for children (University of Virginia, 2011).

North Carolina State University offers a week long day camp for elementary students in grades 3-5 focusing on introductory engineering skills and concepts with students (North Carolina State University, 2011). Sooner Elementary School in Oklahoma City, Oklahoma offers an after school elementary science club organized by parent volunteers and supported by engineering students from the local university. The Sooner Elementary Engineering and Science (SEES) club's goal is to provide engaging hands-on activities that make science and engineering come alive for students (Rhoads, Walden, & Winter, 2004).

Private businesses are also popping up around the country that offer children's programs in STEM disciplines. Children's Engineering Educators, LLC is an example of a private business developed specifically for the purpose of joining the STEM initiative to support teachers in the classroom. This company provides staff development as well as instructional tools and lessons for elementary teachers to incorporate STEM concepts and engineering design activities into their classrooms (Children's Engineering Educators, 2002). Engineering for Kids® is another private company that started in Stafford, Virginia teaching engineering concepts and STEM content to elementary and middle school children through classes, camps and parties (Engineering for Kids, 2011). While these businesses are great opportunities for a select group of children to participate in STEM activities, more needs to be done on a larger scale to prepare elementary teachers to incorporate STEM concepts into existing school curricula in order to provide equal opportunities for all children.

Goals for future elementary STEM education

The call implementing STEM initiatives into the American education system has come from the highest office. President Obama's "Educate to Innovate" campaign has thrust STEM initiatives into the limelight. Efforts are continuing to introduce more STEM learning into existing P-12 curricula, however, the impact of high stakes testing and issues related to teacher knowledge and staff development hinder the process (Brophy, 2008). While school accountability and standards-based

testing are important and will continue into the foreseeable future, incorporating STEM initiatives and concepts into the curriculum are equally important. Institutions of higher learning need to take the front lines to join forces with the current initiatives of the *Partnership for 21st Century Skills* and President Obama's Educate to Innovate campaign. The first line of attack should be in teacher education. STEM concepts such as scientific inquiry, problem-based learning, engineering design and technological activities should encompass the methodology that every elementary preservice teacher receives in their teacher education programs. The United States demands that their teachers are highly qualified, but many lack confidence to teach scientific inquiry in the elementary classroom (Bencze, 2010). Preservice teachers need to be thoroughly prepared to incorporate STEM initiatives into the existing curriculum wherever they teach. By preparing the preservice teachers of tomorrow, we lay the foundation for change.

Second, university teacher educators need to reach out to their community schools' and provide staff development for veteran teachers. Providing instruction and pedagogy on scientific inquiry and technological design in the elementary classroom will help elementary teachers feel more confident to alter their existing curricula to incorporate STEM initiatives. When teachers have positive self-efficacy towards instructional methods, they are more likely to engage students using that method (Ross, 1998). Implementing STEM concepts in the elementary school curricula involves teaching students through problem-based learning and collaboration which resembles the workplace of the future. *The Partnership for 21st Century Skills* focuses on these important concepts in the student outcomes. The 4 C's in the student outcome model represent critical thinking, communication, collaboration, and creativity (*Partnership for 21st Century Skills*, 2004). Many veteran elementary school teachers are in need of professional development to support them in establishing the learning environment called for in these latest education and STEM initiatives.

The third suggestion to help motivate American youth to begin rigorous academic tracks that lead to higher education and careers in STEM disciplines is to provide ample and equal opportunities for early exposure to STEM related concepts. Developing summer camps, classes, and workshops for elementary students to experience hands-on scientific inquiry and technological design activities will engage young learners with STEM disciplines and content that they might not otherwise experience. While students are engaged in STEM activities, they will also gain experience with 21st Century skills such as critical thinking, collaboration and communication that will help prepare them to compete on the global level. Interactive problem-based learning activities in STEM disciplines are innovative and exciting for young learners. It is hypothesized that this type of environment will spark motivation to pursue more advanced math and science courses and lay the foundation for STEM careers. More research needs to be done in this area as the United States moves forward to reclaim their status as global

leaders in math and science.

The Russian's were the first country to launch an artificial spacecraft, Sputnik 1, in 1957. This unannounced success of Russia's advanced technology ignited the world's Space Race. It took a dozen more years, but the United States prevailed and succeeded with the first manned space mission to land on the moon. The Space Race sparked a tremendous increase in spending for education and research in the United States. President Obama's campaign *Educate to Innovate* has initiated similar motivation to help American youth achieve globally at the highest levels in STEM disciplines, but the flames must be fanned. The *Educate to Innovate* campaign calls for collaboration between the federal government, businesses, higher education as well as non-profit groups to provide American youth with STEM exposure and support as explained in this paper. Providing exposure to even the youngest learners may be the key to long-term success for American education. The opportunity for America to achieve high ranking status in STEM disciplines in the world markets lies in the hands of our youth. We can achieve these lofty goals by implementing STEM initiatives as an integral part of the elementary level curricula in America today!

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