Science, Technology, Engineering & Math

SETDA

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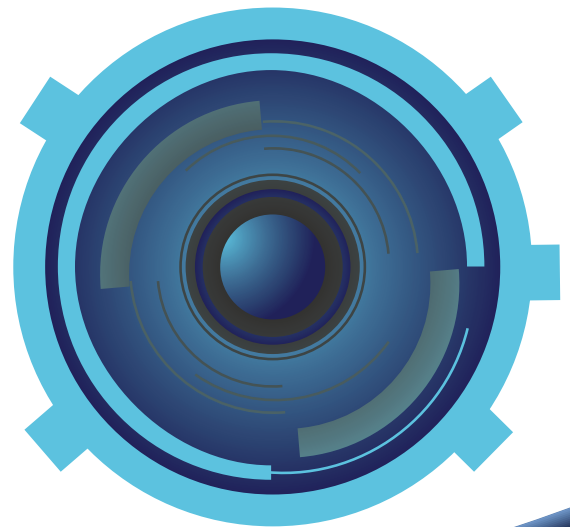
Executive Summary

The students in kindergarten this year will graduate in 2020. It is our responsibility to ensure that our children are prepared to lead our country in the 21st Century and compete in the global marketplace. In order to do that, we need to provide our children with an education that includes a solid foundation in science, technology, engineering, and mathematics (STEM). We also need to encourage the students of today to pursue careers in STEM-related fields. The opportunity cost for not addressing this challenge is too high for our country to ignore. In this paper, SETDA discusses the importance of STEM education, the current state of STEM education, and barriers to implementing STEM education and recommends what stakeholders and policymakers can do to support STEM education.

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What is STEM Education?

STEM refers to the areas of science, technology, engineering, and mathematics. STEM initiatives started as a way to promote education in these related areas so that students would be prepared to study STEM fields in college and pursue STEM-related careers. Schools with a strong emphasis on STEM education often integrate science, technology, engineering, and mathematics into the entire curriculum.

On a given school day, students benefitting from an education that integrates STEM into the learning process may collaborate on an interactive white board, use a simulation program to graph and model formulas through spreadsheets to learn algorithms, manipulate molecules to understand reactions, use handheld devices to collect and analyze data to solve real-world environmental problems, or use sophisticated technology to understand the connections between music and mathematics.
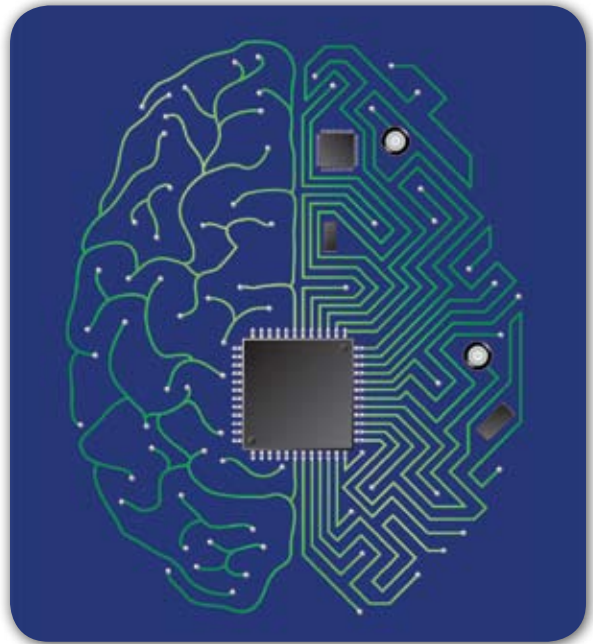
Why STEM Education is Important

Students need an education with a solid foundation in STEM areas so that they are prepared to both work and live in the 21st Century. Since the 1960s, the demand for skills has changed significantly – the demand for routine manual task skills have decreased, while the demand for non-routine interactive task skills have increased significantly.[1] Workforce projections for 2014 by the U.S. Department of Labor show that 15 of the 20 fastest growing occupations require significant science or mathematics training to successfully compete for a job.[2] According to the U.S. Bureau of Labor Statistics, professional information technology (IT) jobs will increase 24% between 2006 and 2016.[3] However, as jobs requiring a solid background in science, technology, engineering, and mathematics are growing – more students are choosing not to major in these areas.

- Enrollment in undergraduate degree programs in computer sciences is more than 50 percent lower than it was five years ago.[4]
- In 2001, only 8% of all degrees awarded in the U.S. were in engineering, mathematics or the physical sciences.[5]
- The U.S. ranks 20th internationally based on our share of graduate degrees awarded in engineering, computer science, and mathematics.[6]
- By 2010, if current trends continue, more than 90 percent of all scientists and engineers will be living in Asia.[7]

> *"Jobs that traditionally offer the best pay and require the most education are growing the fastest. "*
>
> —The American Diploma Project, Connecting Education Standards and Employment

If students continue to pursue degrees and careers in fields other than STEM-related areas, the U.S. will find it difficult to compete in the global economy. Further, the U.S. will not be able to meet its future workforce needs. The U.S. needs 400,000 new graduates in STEM fields by 2015.[8] Microsoft reports that only 14% of students graduating with bachelor's degrees in Washington state have the skills that they need.[9] Without a solid foundation in science, technology, engineering, and mathematics, students will not be qualified for many jobs in the workplace – including many jobs beyond traditional engineering or science-related jobs.

Current State of STEM Education

The initial force behind STEM education initiatives was to develop future engineers and scientists through the implementation of specialty or magnet high schools focusing on science, technology, engineering, and mathematics. There are over 100 schools specializing in mathematics, science, and technology serving 37,000 students nationwide.[10]

While this approach works for students enrolled in these high schools, the majority of kids in most school districts in the country do NOT have STEM school options. Instead, in most school districts, science, technology, engineering, and mathematics are included as part of the entire curriculum – not as a specific focus. Many of these STEM subject areas are not integrated into the curriculum or taught on an everyday basis. For example, 29% of K-5 teachers report teaching science two or fewer days per week.[11]

STEM Education Initiatives

This section highlights some of the current broad-based initiatives to advance STEM education at the national, state, and district levels.

National Initiatives

Several national STEM initiatives are highlighted below.

The National Aeronautics and Space Administration (NASA)

(http://education.nasa.gov/home/index.html) implements programs to advance STEM education with the goal of increasing the pool of scientists, engineers, and mathematicians who will lead space exploration. In the "NASA Means Business" competition, college students compete to develop promotional plans to encourage middle and high school students to study STEM subjects and to encourage professors to involve their students in outreach activities that support STEM education.

Project Lead the Way (PLTW)

(http://www.pltw.org/) is a national, non-profit educational program that promotes science and engineering for middle and high school students. PLTW partners with public schools, higher education institutions and the private sector and currently serves over 175,000 students. PLTW utilizes a project-based learning philosophy where students engage in hands-on, real-world projects and students discover how the skills they are learning in the classroom are applied in everyday life. PLTW's primary goals are to increase the number of students who pursue degrees in engineering and

PLTW at a Glance 2007-2008 School Year:
   States with PLTW programs:
      49 states and the District of Columbia
   Total schools: 2,000
   Total teachers trained: 6,000
   Total counselors trained: 3,500
   Total students enrolled in PLTW classes: 175,000
   Total number of students who have experienced PLTW: More than 300,000

engineering technology programs, and who graduate with these degrees. PLTW is also committed to providing leadership for the continuous improvement and innovation in STEM programs.

The National Consortium for Specialized Secondary Schools of Mathematics, Science and Technology (NCSSSMSST)

(http://www.ncsssmst.org/) supports specialized schools whose primary purpose is to prepare students for leadership in mathematics, science, and technology. Specialized Math and Science High Schools (MSHS) focus on STEM courses where teachers encourage student

NCSSSMST at a Glance
 80 institutional members (secondary schools)
 39,000 students
 1,600 educators
 Over 100 affiliate members (colleges, universities, and corporations)

learning and the development of critical thinking skills. MSHS form partnerships with colleges, businesses, and community organizations to support research and internships.

State Initiatives

Several state-level STEM initiatives are highlighted below.

Arizona STEM Education Center, a coalition of private and public partners, created to promote teacher recruitment, training and retention, generates interest in math and science for pre-school through high-school students, and encourages college students to pursue degrees in STEM-related fields. The Center plans to bring employees from technology, science, and other private sector companies into classrooms to expose students to STEM careers.

The Missouri METS Coalition (http://www.missourimets.com/mx/hm.asp?id=home), an alliance of business, education and community leaders, was created to boost student achievement in math, engineering, technology and science. Some of the METS Coalition recommendations to the state legislature for 2008 include streamlining Missouri's mathematics and science curricula, expanding the pool of students motivated to pursue METS careers through increased scholarship opportunities and higher-education incentives, and providing incentives to recruit and retain high quality P-20 math, engineering, technology and science educators.

> *The Missouri METS Coalition supports incentives to recruit and retain high quality P-20 math, engineering, technology and science educators, and professional enhancement programs and opportunities for all METS educators.*

The North Carolina New Schools Project (http://newschoolsproject.org/page.php), is redesigning 100 high schools across the state so that every student is ready for college, a career, and life in the 21st Century. Thirty-four of those schools have a specific STEM focus and 16 of the redesigned schools have a one-to-one student-to-computer ratio, with an emphasis on integrating technology in the curriculum. In these schools, teachers connect students with the knowledge-based economy. Many of the schools are opening in towns with businesses requiring skilled workers.

The Ohio STEM Learning Network (OSLN) (http://www.ohiostem.org/), is a statewide initiative created in 2007 to provide $200 million in funding to support STEM initiatives for Pre-K-16. Initiatives include attracting undergraduates into STEM disciplines, increasing the supply of STEM researchers in higher education, developing STEM schools, and enhancing professional development for STEM teachers. The OSLN includes a dynamic group of Pre-K-12 education, higher education and business partners. All partners work together to share best practices and innovative ideas. Collaboration is essential for ensuring that all school districts have access to STEM learning.

The Washington Scholarship Program is a program in which Washington state in conjunction with private companies is offering scholarships to students who score well in STEM subjects on state and/or college-entrance exams. In order to obtain a scholarship, students must major in STEM subject areas and agree to work in Washington state after graduation.

District Level Initiatives

Several innovative districts highlighted below have begun implementing STEM at the middle- and elementary-school level.

STEM Curriculum for K-12 Students - Halifax County, Virginia

Since taking over as superintendent of Halifax County Public Schools, Paul Stapleton has been a strong proponent of STEM education. Within 6 months, he established a high school STEM Academy (magnet program) for a select group of 14 students. The following school year, the program was expanded to include over 100 students. The results of the program have been outstanding. Halifax is planning to expand STEM education into the middle and elementary school curriculum and over the next 3-5 years, Halifax plans to introduce a STEM curriculum for all students in grades 1-12.

> *"We initially implemented the STEM Academy to prepare a select group of students for careers in science and engineering. Now, I believe that the skills developed in a good STEM program are beneficial for all students."*
>
> —Paul Stapleton, Superintendent Halifax County Public Schools

Middle and Elementary School Mathematics and Science Programs – Prince William County, Virginia

Three middle schools and two elementary schools in Prince William County offer Mathematics and Science Programs. The programs are designed to challenge and motivate students in science and math through hands-on discovery and exploration, while developing critical thinking skills. These specialty schools stress rigorous academic instruction, strong performance expectations, and high behavioral standards. They use research-based innovative instructional strategies within the framework of a traditional education.

> *Montgomery County, Maryland is in the process of systematically implementing STEM learning for ALL students starting in kindergarten.*

STEM Elementary Schools - The Utica Community Schools, Michigan

The Utica Community Schools (USC) system in Sterling Heights, Michigan, under the leadership of the superintendent, Dr. Christine Johns and her staff, has embarked on

a broad-based initiative where science, technology, engineering, and mathematics are taught through an interdisciplinary approach. Initially targeting grades 3 – 6, teachers and curriculum leaders have been working the last several years to develop STEM modules using the curriculum development templates of CurrTech Integrations (www. currtechintegrations.com). The modules which will be implemented in the district's 29 elementary schools during the 2008-09 school year, adhere to several prevalent guiding philosophies. Among these philosophies are the 5E teaching/learning cycle, Understanding by Design (UbD), problem-based learning, performance-based assessments, inquiry, and formative assessments. All modules culminate in an engineering-based problem, in which science, technology, and mathematics are applied to the engineering process. Along with the written curriculum, various teaching technologies such as student tablets and student response systems are an integral part of the curriculum development and delivery process. It is Dr. John's vision that skills developed using a good STEM curriculum benefit all students, regardless of their future career paths.

> **Benefits of a STEM Curriculum**
> - Enhanced problem solving capabilities
> - Improved mathematics skills
> - Technology savvy student population
>
> *Source: Dr. Christine Johns, Superintendent, Utica Community Schools*

Elementary School Technology Program – Tempe, Arizona
(www.tempeschools.org/schools/scalestechnologyacademy)
Scales Technology Academy, located in Tempe Elementary School District in Arizona, provides one-to-one laptops for all students from kindergarten through fifth grade and focuses on a high-technology curriculum. Scales Technology Academy is one of several school created to appeal to parent's preferences and is funded by a voter-approved $64 million bond. Scales Technology Academy integrates technology into the curriculum and provides a balance between core knowledge and 21st Century skills. Teachers empower students to be independent learners, critical thinkers, and problem-solvers. Teachers use interactive whiteboards, document cameras, and audio enhancements among other technology tools. The entire school campus is wireless, promoting anytime, anywhere learning for all students. Scales Technology Academy learning provides:
- Daily use of technology integrated across the curriculum;
- Access to technology for every child;
- Technology provided for students who might not otherwise have it at home;
- Curriculum that includes 21st Century skills, such as critical thinking, technology proficiency, collaboration, communication, and information literacy; and
- Staff who are specially trained in technology integration.

Over 75% of students at Scales receive free and reduced-price lunches and are from low-income families that do not have access to computers and technology outside the school.

> *"Technology truly transfixes the students' focus. They are 100 percent engaged. They are so engaged, they don't even realize how much of the curriculum is tied in."*
>
> —Veteran Teacher at Scales

Barriers to STEM Education

SETDA has identified some of the barriers to achieving STEM education for ALL students.

What Hinders Districts from Offering High-Quality STEM Education Programs in ALL Schools?

- Curriculum and credit issues
  - Is it a science course, a mathematics course, an engineering course, or a technology course?
- Lack of funding
  - Most states and districts do not provide funding to help promote STEM education
- Lack of qualified teachers
  - Very few graduates are majoring in STEM-related fields and then choosing a teaching career
  - Only 60% of public school math teachers teaching math in grades 7-12 majored in math in college[12]
  - Two-thirds of students taking physical science classes do not have teachers who majored in physical sciences in college or who are certified to teach physical sciences[13]
  - Difficult for STEM trained professionals to transfer to teaching because of certification requirements
- Inadequate policies to recruit and retain STEM-Educated Teachers
  - Teaching STEM requires a different knowledge and skill base at the elementary, middle and high school levels

What Hinders our Teachers?

- Difficult to retain teachers with a STEM background
  - Teachers with a STEM background often leave teaching to pursue graduate school
- STEM-trained professionals often don't pursue teaching because of low compensation
- STEM teachers have difficulty advancing professionally
  - Difficult to conduct research while teaching in the classroom
  - Difficult to continue to learn more about STEM areas while teaching in the classroom

- Lack of adequate preparation for teachers by higher education
    - o Not enough focus on STEM content understanding
- Classroom time constraints
    - o At the elementary school level, low performing schools often spend extra time focused on reading and don't provide adequate time for learning in STEM areas.

What Hinders Our Kids?
- Societal and cultural beliefs that mathematics, science, engineering, and technology are not for everyone. Parents, teachers, and the community say to kids:
    - o "I'm not good in science"
    - o "I don't have the engineering gene"
    - o "I'm doing fine without mathematics skills"
    - o "I didn't need the Internet when I was in school"

> Administrators, teachers, and parents never say that reading is not for everyone!

- Kids don't see relevance of STEM education
    - o In elementary school, science is taught only a few hours a week – not everyday like other core subjects
    - o 29% of K-5 teachers report teaching science two or fewer days per week[14]
    - o Teachers don't show kids the connections between real-life activities and STEM
    - o 50% of students say they will take math courses only as long as they are required[15]
- Difficult to attract and keep kids in STEM careers
    - o Kids don't major in STEM-related fields unless they want to be a scientist, IT professional, engineer or mathematician
    - o Only 8% of college students elect STEM-related majors
    - o Many STEM careers, particularly teaching, don't pay well

Key Recommendations

Where Do We Want to Go?

Early exposure to STEM is critical for our children, and students should not have science or computer lab just once a week. Instead, STEM should be integrated throughout the curriculum for ALL children starting in kindergarten.

> *Strengthening STEM education should be for ALL students – not just the cream of the crop who have access to magnet or specialty school options.*

How Are We Going to Get There?

States and school districts should develop a strategic plan to implement STEM education for all kids beginning in kindergarten, and develop specific targets for achieving these goals. As part of this strategic plan, states and school districts need to demonstrate to the community, especially parents, that STEM education is necessary for all students. States and school districts can look to broad-based initiatives developed in others states and districts for guidance.

In order to provide ALL students with a solid background in STEM, we need to:
- Obtain societal support for STEM education
- Expose students to STEM careers
- Provide on-going and sustainable STEM professional development
- Provide STEM pre-service teacher training
- Recruit and retain STEM teachers

1. Obtain Societal Support for STEM Education

The educational community must advocate and obtain societal support, especially from parents and students for STEM education. As discussed earlier in this paper, a strong foundation in science, technology, engineering, and mathematics is critical for success in the 21st Century. Not only do our students need a strong foundation in STEM in order to be successful in the workforce, as educated citizens, our students need a solid background in these areas so that they can make informed decisions in all parts of their lives – from the kind of car they drive and its impact on their budget, to the type of energy sources available for heating their homes, to the technology needed to stay connected with friends and family.
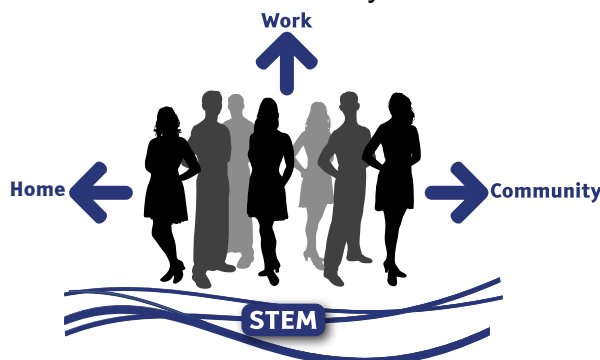
2. Expose Students to STEM Careers

It is critical for kids to see the relevance of a STEM education as it relates to the workforce. Internships and summer job programs help high school students see the relationship between the STEM curriculum and the 21st Century workforce. Listed below are some examples of internships and summer programs for students.

Anne Arundel STEM Magnet High School Internship
(www.aacps.org/stem/resources.asp)
The overall goals of the internship program are for students to:
- Compare and contrast different work environments in order to determine areas of interest and skill
- Develop academic, technical and communication skills necessary for the workforce
- Understand company culture and job responsibilities to recognize the role of a specific career in society
- Demonstrate a thorough understanding of a profession

Goddard Space Center Summer Education Programs
(http://neptune.gsfc.nasa.gov/education/)
These education programs are designed to increase the application of science, technology, engineering, and mathematics (STEM) skills and familiarize students with STEM careers.

SISTER - Summer Institute in Science, Technology, Engineering, and Research
(http://education.gsfc.nasa.gov/sister/default.html)
The Goddard Space Flight Center in Greenbelt, Maryland offers a five day summer institute for the purpose of providing opportunities for middle school girls to explore non-traditional career fields with research scientists, mathematicians and engineers.

Summer Institute of Robotics (SIR)
(http://university.gsfc.nasa.gov/programs/sir.jsp)
The Summer Institute of Robotics is a 2-week residential program at Morgan State University in Baltimore that is designed to provide opportunities for urban high school students to learn and discover the science and technology of robot design and operation, and to encourage students to pursue careers in science, technology, engineering, and mathematics (STEM).

3. Provide On-Going and Sustainable STEM Professional Development

On-going and sustainable professional development focused on STEM areas is critical to the successful integration of STEM education into the curriculum for ALL students starting in kindergarten. Currently, many STEM magnet schools focus on providing students with workplace and 21st Century skills using an inquiry-based approach that includes problem-solving, collaboration, critical thinking, and research. All students can benefit from this approach and teachers need professional development to support it. As more and more technology tools and resources are available, teachers

are able to provide instruction that is engaging, dynamic, and rigorous. Online professional development and online courseware are just a few of the proven effective methods for providing on-going sustainable professional development.

> *On-going and sustainable professional development that involves modeling, mentoring, and/or coaching increases the likelihood that teachers will change instructional practices by almost 90%.*
> - Joyce and Showers, 1992, 2005

- **Online Professional Development:** Online professional development courses provide resources for many teachers throughout a district and/or state. For Algebra, Louisiana offers twelve modules covering topics from "Concept of a Variable" to "Measures of Central Tendency." Each module focuses on a specific algebraic content topic and includes elements of instructional strategies and lesson planning. Furthermore, modules include online readings and resources, interactive activities, online discussion prompts, and optional enrichment activities.

> 26% of teachers report that online professional development is their preferred method for professional development.
> - Speak Up 2007

- **Online Courseware:** Delaware provides access to online courses through eLearning Delaware. Teachers have access to several clusters of courses. In one cluster, teachers learn what types of curricula and learning principles will ensure students' success in the 21st century workplace and post-secondary education. In another cluster, teachers receive the skills and knowledge necessary to implement technology in the classroom through Web-enhanced lessons, project-based learning, and virtual field trips. Teachers connect with other teachers in an online environment to ensure on-going and sustainable professional development. http://www.dcet.k12.de.us/elearning/index.shtml

> Online professional development tools provide resources for teachers in all districts, regardless of geographic location.

4. Encourage Pre-Service Training

We need to encourage pre-service training for our teachers so that they are prepared to integrate STEM learning into the classroom the first day they start teaching. Quality pre-service training provides new teachers with the skills, resources, and experience necessary to begin teaching careers. Here are a few examples of pre-service programs.

> *High quality pre-service training is a strong predictor of both teacher retention and good teaching practice.*
>   - National Commission on Teaching and America's Future

Cincinnati Initiative for Teacher Education (CITE) - CITE is a five-year pre-service teacher education program designed to graduate fully qualified teachers. Teachers are required to obtain two degrees – a bachelor's degree in education, as well as a degree in their specific discipline. Additionally, teachers participate in a one-year internship that combines teaching and professional development. During the internship they work with experienced teachers, faculty, and other interns as professional teams.

> *Nearly 2/3 of teachers cited science as the area they wished had been emphasized in their pre-service training.*
>   - 2004 Bayer Facts of Science Survey

The U.S. Department of Energy, Office of Science: The Office of Workforce Development for Teachers and Scientists (http://www.scied.science.doe.gov/scied/PST/about.htm) offers a pre-service summer internship program for students who have decided on a teaching career in mathematics or science. Students are placed in paid internships in science, math, and technology. Students work with scientists or engineers and are mentored by a Master Teacher who currently works in K-12 education and is familiar with the research environment of a specific National Laboratory.

> *"What you are seeing more of now in schools and colleges of education is a desire to integrate technology in the methodology portion and coursework."*
>   - Thomas Brush, Associate Professor of Instructional
>   Technology, Indiana University

5. Recruit and Retain STEM Teachers

We also need to recruit and retain STEM-educated professionals to the teaching profession. In the next decade, we will need over 2 million teachers - 240,000 of which specializing in middle and high school mathematics and science.[16]

Teachers Learning in Networked Communities (TLINC)
(http://www.nctaf.org/resources/demonstration_projects/t-linc/TLINCresearch.htm)
TLINC gives teacher candidates and novice teachers the support of an interactive network. TLINC provides a professional learning community that combines in-person mentoring with online coaching and peer collaboration to improve teaching quality and student achievement. The TLINC project seeks to achieve the five following outcomes in its three project sites:

- Improved teacher retention
- Accelerated proficiency for new teachers
- Opportunities for all teachers, administrators, and university faculty to become engaged in a learning community that continues to evolve
- Establishment of partnership capacity-building structures and processes that assure sustainability
- Identification of the elements of TLINC that are the source of its power, to identify the essentials for replication and scaling.

The UTeach Program
(http://www.UTeach.utexas.edu/)
UTeach seeks to recruit, prepare, and retain qualified science, mathematics, and computer science teachers. UTeach provides full teaching certification for undergraduate students pursuing degrees in mathematics, science, and computer science degrees. UTeach started at the University of Texas at Austin, and is currently being replicated at 13 universities in the United States through the UTeach Institute and the National Math and Science Initiative (NMSI). As a result, greater numbers of graduates with degrees in STEM fields are choosing teaching careers. Of those who graduated from the UTeach program and started teaching four years ago, approximately 82% are still teaching. The UTeach program incorporates the following strategies:

- Early and active recruitment of college students that begins as early as the freshman year and targets students from diverse ethnic, socioeconomic, and academic backgrounds
- Maintenance of a personally, academically, socially and professionally supportive environment that promotes student retention
- A cohesive professional development sequence that focuses on the challenge of learning math and science, and builds pedagogical skills and knowledge at progressively deeper levels
- Development of domain classes that promote a deeper-level understanding of the subject material and demonstrate effective approaches for technology use in the learning process
- Utilization of experienced master and mentor teachers who model best-practices as they teach in college classrooms and guide students in their field experiences
- Early and on-going guided field experiences in a variety of public school settings with diverse student populations
- Integration of technology competencies in all aspects of the program

- Structured assessments throughout the program that actively involve students in an on-going self-assessment of their own professional growth and development
- Establishment of a coherent and viable network (electronic, personal, institutional) for continuous professional development of program graduates
- Continual refinement of the UTeach academic program based on evaluation data and educational research
- Collaborative governance of the program that is committed to the management of program curriculum, resources and instruction

Additional Strategies for Recruiting and Retaining STEM Teachers
- Recruit mid-career and/or retired professionals to teach STEM
- Provide an alternative certification process for STEM teachers
- Provide financial incentives for students to pursue careers as STEM teachers

California Mathematics and Science Teacher Corps at California State University, Dominguez Hills – This program was created to provide training and credentials to retired and laid-off aerospace workers interested in becoming elementary or secondary mathematics and science teachers. Students receive specialized training based on their advanced knowledge and experience in the field. Students spend one year in the program working with peers, observing, tutoring and teaching in schools while taking courses in teaching methods, motivation, learning, and classroom management.

George Washington University, Washington, DC Teacher Preparation Program - QUEST (http://www.gwu.edu/~quest/about/index.htm)
The QUEST program is designed for recent college graduates and professionals transitioning from other fields who want to become middle and high school teachers. The QUEST Program provides the coursework for initial teacher licensure leading to a Master's in Secondary Education (M.Ed.). and licensure eligibility for those who are interested in teaching secondary Art, English, English as a second language, foreign language, mathematics, computer science, science (biology, chemistry, physics), and social studies.

Conclusion
In conclusion, education stakeholders have a responsibility to ensure that all students have access to high quality instruction in the STEM areas. STEM is a critical component of transforming our educational system and ensuring our students are prepared to thrive in the 21st century global economy. SETDA will continue to add resources and programs to:
http://www.setda.org/c/document_library/get_file?folderId=270&name=DLFE-246.doc

Endnotes

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