Implementing a Dual System of Education to Promote Science, Technology, Engineering and Mathematics

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ABSTRACT

There is a growing concern in the United States regarding the declining state of education and college enrollment for degrees in the areas of Science, Technology, Engineering and Math (STEM). As part of a STEM Outreach program, The MITRE Corporation is partnering with educational foundation organizations to encourage school districts to seek out and take advantage of new prospects for students. These include opportunities to learn and apply STEM-related constructs and emerging technologies in a contextually relevant setting. This paper presents a model for integrating classroom and on the job activities to enhance the overall educational experience. A case study is presented highlighting MITRE's STEM program, including: increasing awareness of STEM education and career initiatives, building and maintaining partnerships with Colleges, High School STEM programs and other Community Educational Organizations, and providing internship opportunities.

Keywords: STEM, Engineering, Education, Internship, Apprenticeship, Career Academy

1. INTRODUCTION

In response to a growing concern in the United States regarding the declining state of education and college enrollment for degrees in the areas of Science, Technology, Engineering and Math (STEM), the MITRE Corporation is taking an active role working to encourage school districts to enhance and provide additional opportunities for students to learn and apply STEM-related concepts through a balance of classroom instruction and internship-based hands-on experience. In this role, MITRE has been influential through outreach activities consisting of but not limited to participation in State and Federal Government Summits, providing internships to students, establishing partnerships with College and High School Engineering Magnet programs, teaching at local universities, and judging science and technology events and competitions.

Additionaly, MITRE has initiated partnerships with non-profit organizations such as the Career Technical Education Foundation (CTEF) to help implement a dual system of education that integrates in-class learning at the high school and college level with hands-on internships with Industry to provide an enriching educational experience for students in STEM topics while establishing a pipeline of excellent talent for Industry [1, 12].

This paper presents a case study of MITRE's STEM program, highlighting: paid internships for High School and College students, shadowing programs for High School students, bootcamp training sessions for local students and teachers, summer technology camps and field trips for interns/co-ops, and summer distributed workshops that stimulate interns across several geographic locations by working together to solve realistic sponsor challenges.

2. BACKGROUND

STEM was coined in the 1990s by the National Science Foundation to formally recognize the interlinking and importance of the fields of study in "Science, Technology, Engineering and Mathematics" and to promote overall enhancements in skills, education and standards in these fields as a whole.

STEM Employment and Growth Projections					
	May 2008 Employment	2010 Employment	2018 Employment	Number change: 2008-2018	Percent change: 2008-2018
Life, Physical, and Social Science Occupations	1,110,420	1,255,700	1,469,400	214,000	16.7%
Computer Specialists Occupations	3,464,180	3,717,300	4,529,400	812,200	22.4%
Architecture and Engineering Occupations	2,480,240	2,820,100	3,101,900	282,000	11.6%
Mathematical Occupations	107,150	116,000	139,000	23,000	17.5%
STEM Occupation Employment Total	7,161,990	7,909,100	9,239,700	1,331,200	16.8%
US Total Employment	127,097,160	150,931,700	166,205,600	15,273,900	10.1%
% of Total Employment	5.6%	5.2%	5.6%	n/a	n/a

Figure 1. Projected Market for STEM Professions

As shown in Figure 1, the projected demand for STEM professionals is expected to increase over 16.8% from 2008-2018, adding more than a million new jobs to the workforce [9, 10, 11]. In the May 2011 monthly labor review by the United States Department of Labor, the Bureau of Labor and Statistics listed the top growing needs in the workforce to be STEM occupations, including computer specialists such as developers and systems engineers, network engineers, information security engineers as well as civil and mechanical engineers. This trend is expected to grow.

In order to meet this demand, there must be a qualified workforce that is prepared to fulfill these occupations, thus driving the need for STEM education. However, there are many metrics, reports and examples found in literature today and over the past several years to show concern in the declining state of STEM education in the United States [14, 15]. For example, in the 2006 United States National Academies report to the United States Congress, several alarming points were made related to compromising America's position as a leader in technology, engineering and creating innovations [5]:

- The performance of 15-year-olds in the United States who in 2006 ranked 25th in math achievement and 21st in science achievement.
- The United States has fallen in international rankings from 2nd in 1995 to 15th in 2008.
- The popularity of computer science as a major for incoming college students has fallen more than 60 percent between 2000 and 2004.
- The turning point for interest in science & engineering occurs in Middle School.

To compound this concern further, the Bureau of Labor and Satistics also predicts a trend that due to low salaries for STEM teachers, over 25000 STEM teachers currently in the education system may leave the teaching profession annually [9, 11]. As the United States Department of Education seeks to elevate both the teaching profession and STEM education [4], there is a need for a renaissance in education to include:

- A heightened focus on Science, Technology, Engineering and Math skills;
- Skillfully integrated academic and technical learning paths;
- Increasing America's talent pool by improving K-12 science and mathematics education;
- Strengthening the skills of teachers through additional training in science, math and technology; and
- Enlarging the pipeline of students prepared to enter college and graduate with stem degrees.
- Increased focus on Industry certifications as well as integration with industry to help boost education through understanding real value in the workplace.

Throughout the remainder of this paper, we will discuss a model that attempts to address some of these needs, and how MITRE is responding to help enhance the educational system as a key Industry partner.

3. DUAL SYSTEM EDUCATIONAL MODEL

Quality STEM education programs, such as the program offered by Project Lead The Way (PLTW), seek to engage students in activities, projects, and problem-based learning, which provides hands-on classroom experiences [6]. In such an environment, students create, design, build, discover, collaborate and solve problems while applying what they learn in math and science. They're also exposed to STEM fields through professionals from local industries who supplement the real-world aspect of the curriculum through mentorships and workplace experiences.

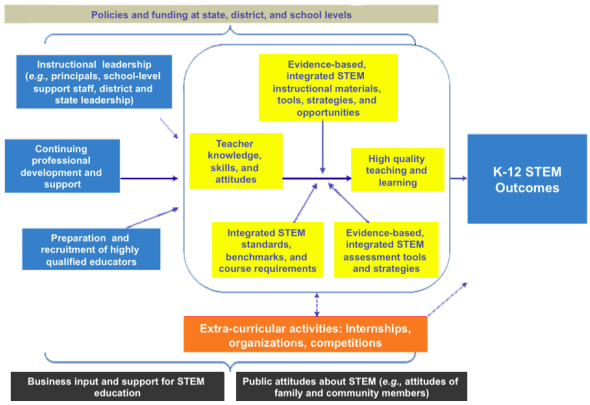

Figure 2. Key variables influencing improvement in STEM education

Figure 2 depicts key variables influencing improvement of STEM teaching and learning in K-12 that have been identified through research [13]. By considering all of the variables and systematically strengthening each component, improved outcomes are more likely to be realized.

A key model to enabling a successful STEM program that attempts to address a balance of each of these variables is referred to as the dual system of education [1, 8]. This

model reflects industry support for educational career academies through focused engagement with schools and through internships and/or apprenticeships. In this model, Academic and Industry partners share responsibility for education and training. The Career Academy assumes the responsibility for teaching the required curriculum content including theory and practical application. Industry provides the career academy financial support and the training necessary to familiarize the trainee with the technological and organizational aspects of the work processes within the company.

Advantages of the Dual System for the Industry partner include:

- Secures the skilled labor needed
- Reduces the costs to train for positions within the company
- Increases motivation and loyalty to the company
- Trainee receives job specific qualifications
- Productive performance of trainee

Advantages of the Dual System for the Student include:

- Recognized Industry Certification
- Increased prospects for employment upon completion
- Theory and practical application of curriculum
- Certain degree of independence through an "earn while you learn" program

The financing of such a model would also come from multiple sources, include Industry partners who would contribute the largest share through donations, mentoring and providing employment opportunities for students. Other financial sources would come from other funding as available from State and Federal Agencies Grants.

This model has been implemented successfully in a number of schools by CTEF, and shows great promise [1]. The potential benefits of this model provide the opportunity for the successful Career Academy Graduate to:

- Earn Industry Certification and/or
- Earn college credit upon successful completion of each course while attending the Career Academy
- Apply to the University of their choice
- Enter gainful employment either with their own training company or another company

The collaborative partnership between Industry and the Educational system represents a model that has been used successfully for years in countries throughout the World, such as the one used throughout the Germany/Austria region [8]. Bringing this model to the United States has shown great promise for the future.

4. MITRE's Role as Industry Partner

From an Industry perspective, science, technology, engineering and mathematics are fundamental components to our professional existence, past and future. STEM initiatives provide youth an opportunity to gain exposure to real world applications of STEM disciplines, helping to see both potential and value.

The goal is to inspire young people to be science and technology leaders. STEM initiatives help to meet this goal by engaging them in exciting programs that build science, engineering and technology skills, inspire innovation and foster well-rounded life capabilities such as self-confidence, communication and leadership.

MITRE is doing its part to help our Nation in addressing STEM concerns. As part of our public interest duty, it is important for MITRE to continue to do this. STEM is fundamental to our business and we need to help groom qualified talent in our core competencies. Our involvement in STEM helps us to do this. By having a vibrant STEM outreach to colleges, k-12 schools and communities, we hope to grow and motivate our future engineers. There are many ways in which MITRE is involved in promoting STEM in our community. Examples include government influence, community and school outreach (e.g. teaching, judging, science fairs, robotics competitions), partnerships with schools (high school and college), and internships. The following section highlights a case study of MITRE's involvement in helping to make the dual system of education a successfule model.

5. CASE STUDY HIGHLIGHTS

Each year, MITRE is actively engaged in STEM outreach across many locations in the United States. At a corporate level, this outreach includes the hiring of over 200 interns each summer from various Universities, colleges and more recently high schools. These interns typically experience a balance of hands-on work experience along with various enrichment activities to promote STEM. Over the past three years in particular, MITRE has partnered with CTEF to become an active sponsor with local High School engineering and technology academies in support of the dual system model. The case study described below highlights the

internship opportunities provided to 19 students across three MITRE site locations during this time period.

The most important part of the internship was working on real world projects alongside MITRE engineers. These MITRE interns gained valuable computer engineering and software development experience through their support to direct funded projects for MITRE's United States Government sponsors as well as for MITRE internal research. A sampling of these projects is described below [2, 3].

Direct Funded Projects

As part of an Agile engineering team, our interns worked to create an infrastructure to collect, store and access socio-cultural information for the Afghanistan/ Pakistan Center of Excellence (AF/PAK COE) at Central Command (CENTCOM). This work entailed network infrastructure integration, software development and social media tool examination.

Several interns were part of a distributed team building gadgets to be used in a composable dashboard for the Partnerships for Americas Collaboration Center. These individulals learned the fundimentals of Java development and widget integration via mashups.

Under a Department of Defense (DoD) sponsor task, a team of two interns created a desktop application, *Moving Target from Video (MTV)* that provided playback, annotation, geo-location and archiving tools for exploiting video streams. This application eventually served as the analyst tool for Full Motion Video Analysts.

In support of the Air Force Enterprise Network, the interns worked on a technology forecasting roadmap, a web application for automatic generation of engineering reports, diagrams, and machine assisted auditing. Working remotely with teams across MITRE, the interns developed Java server pages to query a database and display timeline information.

Learning Ruby on Rails was an opportunity for interns to work on the Semantically Enabled Dynamic Discovery and Delivery (SED3) project. They worked on developing a collection of database tools to make deployment and backup of production data easier to understand and more efficient.

Our interns have supported our customers secure mobile initiative project by demonsrating the flexibility of agile software development techniques in the mobile device development environment. They showcased several on going mobile application development projects as well as the agile process used to achieve them.

In parallel with the stand up of a DoD customer's networking experimemtation lab, several interns were instrumental with the integration, installation and shakedown of OPNET network modeling software. This experience exposed the interns to state of the art network and modeling tools that would never be part of an ordinary engineering curriculum.

Additional Activities

In addition to direct funded projects, the interns participated in other activities to supplement their professional experience and learn more about MITRE and our sponsors.

Bootcamps: Students and incoming interns often lack exposure to many of the key technologies and concepts that play important roles at MITRE. To address this issue, Bootcamps were developed to foster understanding of the core mechanics on these subjects. Bootcamps are short (2-4 hours) classes mixing veteran instruction with hands-on exercise, providing students a fundamental working knowledge of course material. This exposes the students to key terminology, provides a foundation for future learning, and enables immediate participation in related tasks. The end goal is to teach students enough material to hit the ground running in the subject, supporting an effective 'on the job' learning experience. Example bootcamps include topics such as introduction to programming, object-oriented development, mobile development, agile engineering and cyber security.

Fireside Chats: Every Wednesday during lunch local MITRE employees met with interns to discuss their major projects. These "Fireside Chats" provided the intern insight into some of the technical areas that MITRE has focused on recently. Ranging from socio-cultural database management to intelligence integration, these chats were reinforced by visits to our sponsors.

Figure 3. Aerospace Camp

Aerospace Camp: As depicted in Figure 3, interns traveled to Colorado Springs for site visits to MITRE and the United States Air Force (USAF) Academy. This summer field trip provided the interns an introduction to USAF Space Operations; orientation on the USAF Academy and its ongoing research including the Unmanned Airal Survailence (UAS) Program; UAS Research Center and Physics lab; and hands-on participation in live flight UAS experiments.

Distributed Workshops: The Air Operations Center (AOC) workshop was a distributed event between MITRE Bedford, Colorado Springs and Tampa to expose the interns to a real-world Air Operations mission in a simulated environment. The AOC workshop demonstrated distributed AOC with Full Motion Video (FMV) processing, exploitation and dissemination (PED) while collecting and archiving data sets, imagery, and video intelligence products for use in future exercises. The Bedford interns operated an AOC node using common USAF applications for mission planning and ATO production. In responding to various scenario events, they planned out UAS operations for the Colorado Springs node to carry out. The C-Spring interns, with the USAFA cadets, flew the daily missions with Kadet Senior, a commercial RC plane that has been modified to include an autopilot, a GPS system, and a camera. The video and INTs collected in Colorado were sent to the PED node in Tampa, where the intern "analysts" processed and exploited the information looking for clues, patterns and items of interest. Pertinent information was sent back up to the Bedford "AOC" where the interns planned for the next day mission.

Industry Day: MITRE hosted dozens of sophomores from local Florida high schools in an engineering industry day sponsored by CTEF. MITRE introduced the students to cyber security topics, provided an overview of MITRE, and led discussions on what it's like to be an engineer and what we look for when hiring for engineering positions. For fun, the students joined in a marshmallow challenge in which they had to build a tower using marshmallows, spaghetti, string and tape.

Teacher Quest: Teacher Quest is a professional development program for teachers. It works with science, math and technology-based businesses to match teachers with programs to work during the summer and gain industry experience to take back to the classroom. MITRE participated in Teacher Quest by providing summer employment to Computer Science teachers from local high schools. By doing this, teachers can remain current with skills, technologies and application of engineering principals in real world settings. This allows them to return to the class room with refined knowledge and experience to pass along to students.

Robotics: FIRST is an organization focused on inspiring young people to be science and technology leaders, focuses on creating programs to partner education with industry professionals to build science, engineering, and technology skills while inspiring innovation and fostering communication and leadership skills [7]. MITRE actively participates with FIRST by serving as mentors for high school robotics teams in fields such as software, electronics, mechanical and computer-aided design.

Cyber Security Classes: As part of a cyber-focused STEM initiative, MITRE and its interns took part in developing a cyber security course for high school students. The course is aimed at making the students more aware of security issues in the cyber realm. It provides a comprehensive overview of security issues that will provide students with a good foundation for self study or continuing education in the cyber field. In addition, the course will teach concepts that are required for many cyber security certifications.

Capture the Flag Distributed Cyber Event: MITRE hosts an annual Cyber Grand Challenge during the summer internship program. This Grand Challenge, while focused on MITRE interns, is open to particiaption from surrounding colleges and high schools across the US. The objectives of this initiative are to increase awareness about MITRE and its role in information security, facilitate information exchange across institutions, and create a hands-on learning opportunity in security Mission and Information assurance emulating real world situations. To achieve these objectives, the interns and students form teams and participate in a distributed competition that will test the cyber security skills of the participants. The primary focus is on defensive skills, but knowledge of other security related fields will also be tested. MITRE interns will either participate in the high school division or the college division, and the competition is organized in such a way to encourage collaboration and communication between the two divisions.

By combining direct project work with a variety of extra activities designed to provide interns with comprehensive exposure to the engineering profession, each intern is provided multiple opportunities to gain hands-on experience with various engineering disciplines, as well as assess their interest in a possible STEM career. In addition, MITRE is able to assess each student extensively, both from a possible pipeline perspective and for ways to motivate the student further in STEM concepts. The goal is to help each student to be able to return to the classroom and more easily understand the

theory and concepts being taught. When this happens successfully, the full potential of the dual model can be realized.

6. FUTURE WORK

Future STEM work at MITRE will continue to focus on providing educational and internship opportunities for students and teachers in the hopes of enhanceing and motivating STEM interest and education. In particular, MITRE is looking to create a professional cyber security pipeline by partnering with government sponsors, national labs and orgranizations such as CTEF to develop a formal cyber security internship program.

7. CONCLUSIONS

This paper presents the results of implementing a dual system of education through a partnership between MITRE and a number of educational academies.

Through partnerships with organizations such as CTEF that are implementing this model, MITRE has taken an active role as an Industry partner to demonstrate the impact that can be made on students. In the case study example discussed in this paper, of the 19 students who participated during the three year time period across three MITRE locations, 4 students have become MITRE full-time employees, 5 continue as MITRE co-op students in as they complete college, 3 continue as MITRE high school interns, 6 are pursuing other STEM related opportunities and 1 is currently pursuing a non-STEM path. This roughly translates into 60% on track for MITRE's pipeline, and an additional 30% on track for pursuing STEM careers. These results show great promise for this model.

By combining the ingredients of :

- Understanding and embracing the concepts and skills of science, technology, engineering and mathematics
- Passion to make an impact
- Self-confidence to take on new challenges
- Spark to innovate

Young people can accomplish just about anything in superhuman ways, thus creating the kind of breakthroughs and innovations the world desperately needs. Through its STEM initiatives, MITRE is helping to promote future technology and engineering leaders. The dual system of education is a very promising approach to revitalizing STEM education. The partnership with CTEF, a recognized leader of implementing this model in the United States, has proven to be a rewarding experience for both MITRE and the many students that have been part of this experience.

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