Editorials

The Need for Improved STEM Education and the Opportunities Available

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In the February 2012 Pew Research Center report "Young, underemployed and optimistic" reports that people under 30 have been the hardest hit by the recession. Among all 22-34 year olds fully half (49%) report they have taken a job they didn't want just to pay the bills, with 24% saying they have taken an unpaid job to gain work experience. Pew Research Center also found that among 18-34 year olds who are employed, less than half (46%) say they have the education, training and skills necessary to get ahead in their job or career. The only exceptions were the young adults with STEM skills and degrees. Even these young adults indicate that a STEM major such as nursing or engineering is not enough. STEM college graduates need internships and hands-on experiences to open doors to their first paying jobs and provide them with the skills necessary to become professionals.

As the Director of Global STEM Initiatives for Discovery Education and a STEM educator for 29 years I know from first hand experience the impact that STEM can have on students. My dissertation research "Which factors in the learning environment lead to improved test scores on the Biology End of Course exam?", indicated that struggling students reading several years below grade level could be successful in science when they were first engaged with hands-on inquiry and had options other than reading to acquire new content. My research also explored the impact of being mentored by a respected adult who expected the student to be successful. When students have the opportunity to meet and work with someone in a STEM career, it opens their realm of possibilities for their future.

For that reason it is paramount for educators to find ways to insert real-world problem solving into their lesson plans. Besides the fact that this is the most effective way to engage and challenge students, it is exactly what the Common Core State Standards demand in our classrooms. Teachers are being challenged to create interdisciplinary units that allow students to triangulate texts, challenge their preconceptions/misconceptions, apply the standards of mathematical practice to a variety of situations and collect and analyze data. The outcome of their learning should be a well constructed and well communicated solution to the problem with which they were originally presented.

At Discovery Education we work to empower K-14 teachers to have the confidence to do just that. Our resources include high quality digital resources to provide the real world problem or context for students, virtual labs/simulations that provide students with the opportunity to create prototypes/solutions, and try them out many times. Our digital literacy resources can be read aloud to struggling readers, can be translated into a variety of languages and can be accessed at different lexis levels. Our offerings include hands-on inquiry opportunities and competitions for students to develop science inquiry, math and communication skills. Discovery Education includes engaging stories of STEM professionals so that K-12 students can begin to learn about the new careers in STEM that are available to them. The assessments we have created provide students with web 2.0 tools to communicate all they learn in these engaging experiences.

Besides being exposed to engaging and rigorous STEM teaching and learning, students need the opportunity to employ their creativity in problem solving. Summer immersion experiences that include camps, clubs, and travel provide a spark that will motivate students to take the rigorous STEM courses required in high school and college. These immersion experiences should include an opportunity to do some long-term research on a topic of interest to the student with a mentor. This could be in conjunction with a local institution of higher learning, a local nonprofit, or a STEM company. It is critical for students to begin to see themselves as someone who can be successful in STEM fields, if they are to continue to progress in the STEM pipeline.

Another focus of Discovery Education is to connect STEM companies and their workforce developmental needs to the content and standards teachers are required to teach. This either takes the form of curriculum units, a competition, virtual job shadows, or virtual internships. Examples of this include the 3M Young Scientist Competition for 5th-8th grade students and the Siemens "We Can Change the World Challenge" for K-12 students. Both of these partnership competitions provide students with an opportunity to solve a real world problem, earn cash prizes, trips, and scholarship money. 3M and Siemens understand it is critical for their future workforce development needs to engage our nation's youth in STEM problem solving. Discovery is also currently working with several STEM companies to develop virtual job shadows and virtual internships, so that no matter where a student lives they will have the opportunity to experience the context of new and developing careers.

In spite of the high unemployment rates and the recession our country desperately needs people who can address complex issues, collect data, analyze it, and create innovative solutions. These people also need well developed communication skills that includes expertise with technology. The National Academy of Engineering has generated a list of 14 Grand Challenges of Engineering that humans must overcome if we are to survive as a species. These challenges include: finding and providing economical sources of energy, providing clean water to all parts of the world, securing cyberspace, engineering better medicines, providing a better urban infrastructure, advancing personalized learning and, reverse engineering the brain. These people will become the innovators and entrepreneurs who can improve the quality of life for us all.

The Direct to Discovery (D2D) Program at Georgia Tech

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For almost a decade, Georgia Tech has offered the "Direct to Discovery" (D2D) program to high school students in Georgia, California, Ireland, Canada, United Kingdom and Australia. The D2D program interactively brings both the science and the scientist virtually into the classroom using high definition (HD) real-time videoconferencing over advanced fiber optic research and education (R&E) networks (e.g., Internet2, National LambdaRail, PeachNet, etc.). By developing meaningful partnerships between industry, researchers and the K-12 classroom, D2D has used advanced R&E networks to cross the chasm between outdated content currently available in most K-12 STEM textbooks and the true innovation happening at research laboratories, industrial sites and universities.

Perhaps the most exciting aspect of D2D is the connectivity it provides to remote students enabling their use of high-tech equipment that they might never be exposed to – even in college. The realism provided by the scientist when they discuss how PV=nRT really does matter, or why one might need to convert °C to °F, or differentiate between the molecular structures of acetylene and methane allows the K-12 student to authentically put to practice what was previously bound in a textbook.

D2D courses have been collaboratively designed, developed, and delivered jointly by the high school teachers and Georgia Tech researchers. Both qualitative and quantitate measures have shown that the D2D program has been able to significantly boost learning and interest in Science, Technology, Engineering and Mathematics (STEM). By connecting University-based scientists and their laboratory research with K-12 students in their classrooms via the HD video-conferencing, a scientist's equipment (e.g., scanning electron microscope, carbon nanotube growth furnace, telescope, etc.) and the scientist can come "into" the K-12 classroom. D2D has created dozens of interactive sessions covering topics from materials science, to chemistry, to physics, to astronomy, to biology and many others all with the same end effect -- inspired students and enriched learning experiences. The effort continues to expand and evolve and additional participants are constantly being added.

In a popular D2D exposure, students learn about carbon nanotubes (CNTs) -- what they are, why they matter, and how they're grown. They learn about how different 'recipes' for growing CNTs produce differing results. The students are engaged and actively participate in every step of the CNT growth process. After the CNTs are grown, the samples are examined under a scanning electron microscope (SEM) where the students are able to view first hand, in stunning definition, the results in their classroom from their earlier CNT experimentation.

In this era of "no child left untested", the D2D program brings several critical components together in an innovative, teacher-driven learning event that meshes with required curricula elements. D2D researchers work together with teachers to create problem-based learning activities based upon active 'real-world' research that is transparently connected to the remote classroom. This collaborative instructional model builds upon past observations that students do better when they are engaged in authentic, research-based curricula. The hypothesis being tested at the base of this D2D program is that direct and interactive access to scientists and their research creates engaging learning opportunities for students.

Technology in the classroom is not new, but the adoption of the Common Core Standards (CCS) and the College and Career Readiness Profile Index (CCRPI), along with ubiquitous social media and unprecedented access to learning resources via modern technology has escalated K-12 instructional opportunities to new levels.

D2D provides K-12 classrooms with engaging role models for STEM careers and up-to-date professional development for K-12 STEM teachers. Engaging curricular enrichments that inspire STEM learning are provided, and the collaborative development model ensures that content will be aligned with relevant standards. The model has been used to establish collaborations between K-12 classrooms in multiple nations, and in multiple STEM fields. Please visit http://www.directtodiscovery.org/ for additional information.

Two Approaches to Promote STEM Research for Traditionally Underrepresented Students: Direct to Discovery & the Union Point STEAM Academy

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Quality research experiences among K-12 students who are traditionally underrepresented in STEM (e.g., female students, students of color and from poverty) occur infrequently in public education[1,2]. STEM programs that include research opportunities are most often found in independent schools or public schools that serve more privileged populations[3]. When underrepresented students do experience STEM research, it usually occurs in urban areas where universities that provide K-12 outreach may be located close by. Challenges of access to student research for underrepresented populations[4,5,6,7] require innovative programs that bring these experiences virtually to these students. For those schools that lack the technological infrastructure to provide virtual research, more creative school structures that can withstand organizational change must be created to increase the likelihood for quality STEM student research to occur.

An example of a long-term successful program resulting in underrepresented students participating in current, scientific research with STEM experts is the Direct to Discovery Program (D2D), developed through a partnership between the Barrow County School District and the Georgia Institute of Technology[8]. This innovative program brings STEM researchers and their laboratories into the classroom through real and virtual technologies, enabling collaborative, applied learning experiences for both teachers and students. The general structure of the D2D program involves teachers collaborating with scientists and engineers to adapt the teacher's curriculum to the research of STEM experts. Real-time virtual sessions are held through High Definition videoconferencing while students experience this research in action. Teachers and students may also participate during the summer at Georgia Tech. As part of the D2D model, my students and I participated with a research scientist and an engineer, Dr. Jud Ready and Dr. Greg Book, in their research on carbon nanotubes (CNTs) through virtual sessions. This work studied chemical vapor deposition, photovoltaic cell application of CNTs, CNT uses for aeronautical materials, and scanning electron microscopy as a tool to understand and improve CNT growth, process, and design[9]. The experience began during a summer where I conducted original research in Georgia Tech laboratories with Dr. Ready, Dr. Book, and their graduate students to further understand their research. This summer internship occurred through the Georgia Internship Fellowship for Teachers (GIFT) program developed by the Center for Education Integrating Science Math and Computing—CEISMC[10]. That summer I began tailoring my curricula (General and AP Chemistry) around the upcoming research sessions and created an action plan for the following year. This research experience proved to be indispensable to bridge the gap between student knowledge and expert knowledge. For two years after this summer experience, my students and I experienced the research virtually with these experts.

We began to see renewed student interest in the STEM disciplines and in scientific research especially for our underrepresented students. A community of practice[11], emulating what one would find in research and engineering at University laboratories, sowed the seeds for post-secondary participation in STEM for many of these students. The success of the program depended on discussions with experts who could speak the language of the students, a teacher serving as an interpreter of the research, and the experience of students in a classroom culture of research and inquiry. The percentage of students enrolling in Georgia Tech and other high quality STEM universities increased by a magnitude of ten within the first few years; this particular high school only had one student in the previous seven years to enroll at Georgia Tech.

Innovative programs such as D2D are difficult to launch and even more difficult to maintain. K-12 education is at the mercy of state and national mandates, high teacher and leadership turnover, and local "regime" change at the building and system level. Each of these changes is often marked by a shift in priorities for curriculum and funding. A Race to the Top, Innovation Fund grant ($1.7 million) provided the funding needed to continue D2D and take the program to the next level for Barrow County[12]. For those schools that either do not have the technological infrastructure or access to funding to support similar programs, they must create mechanisms within the school governance and curriculum to compensate for institutional changes. These structures can be found in STEM schools that focus on inquiry, design, and research such as public charter schools and theme schools. These school designs may provide that much needed buffer against organizational and policy changes that negatively impact a school culture and vision dedicated to student research in STEM. An example of such a STEM school is the Union Point STEAM Academy (UPSA), which we are currently converting from a traditional public school to a public charter school[13]. The current charter petition for UPSA defines certain curricular mechanisms needed to develop a school culture of inquiry and research[14]. Opportunities for research in rural, high poverty schools must begin in the younger grades in order for quality projects to be produced at the high school level. As a project-based learning school, each grade at the Union Point STEAM Academy will enter in formal competitions such as Science and Engineering Fair, First Lego League, TAG for STEM, and the National STEM Video Game Challenge. The research projects that ensue will serve as the anchor for interdisciplinary learning across subjects. Only a few competitions will be chosen each year so that students can continue the process of conducting research over time in a manageable way.

Similar to scientific research in University or biotech laboratories, quality research projects and experiences occur slowly, methodically over the course of many years. As students focus on STEM each year while developing creativity and innovation through an arts and design component, we expect that our students will think very differently than their traditionally educated counterparts[15]. As they enter high school, our students will be more likely to produce exemplary research projects that may be published. Similar to what we have found for the D2D program, we hope that integrating research into the school culture in this way will inspire students to seek STEM secondary schools and careers. And hopefully, the school structure will help keep these school goals intact for years to come.

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