ITEST Engineering Model

Building a Better Future for STEM Learning

First in a series of replicable models emerging from the ITEST experience

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Executive Summary

This report shares an Engineering Education Model drawn from the experiences of projects funded by the National Science Foundation's Innovative Technology Experiences for Students and Teachers (ITEST) program. The model is a result of two year's effort by the ITEST Learning Resource Center at EDC and the ITEST community to explore the degree to which evidence-based, replicable models are emerging from the ITEST experience. Working from a framework developed for this purpose, six projects representing the ITEST Engineering community of practice convened in August 2011 to draft the ITEST Engineering Model presented in this report. The model was refined during the fall of 2011 and subsequently vetted with the full ITEST community at the 2012 ITEST Summit.

The ITEST Engineering Model illustrates that participation in ITEST Engineering projects leads to increased interest in STEM careers; increased STEM learning; increased engagement in, motivation, and understanding of the relevance of the ITEST projects to academics; and an increased understanding of Work Skills/Engineering as a tool for 21st-century learning. The ITEST projects documented these outcomes in several ways, including using pre-post tests to measure increases in content knowledge; the tests found both high levels of retention and increases in youth interest in engineering.

The ITEST Engineering projects also identified a set of common elements—including "a focus on activities that motivate students to develop interest and skills," "involvement of industry mentors/scientists/engineers," and "use of the scientific process and/or the engineering design process"—which were put in service of achieving the above outcomes. The Engineering Model includes a sampling of theoretical foundations from which the program elements arose, as well as highlights of numerous studies that support the ITEST approach.

The ITEST program was established by the National Science Foundation (NSF) in direct response to current concerns and projections about the growing demand for and shortages of STEM (science, technology, engineering, and mathematics) professionals in the United States; the program seeks solutions to help ensure the breadth and depth of the STEM workforce. Since 2003, ITEST has funded more than 195 projects focusing on engineering; computer, biological, and environmental sciences; and mathematics, impacting more than 225,000 students, 8,000 educators, and 3,000 parents and caregivers.

Exploring Models of STEM Education Emerging from the ITEST Experience: An ITEST Engineering Model

Over the past two years, the ITEST Learning Resource Center (LRC) and ITEST community have been exploring the degree to which evidence-based, replicable models are emerging from the ITEST experience. We chose to move in this direction for a number of reasons:

- To deepen our analysis and provide a common framework for the synthesis of lessons learned in the ITEST experience
- To leverage lessons learned in individual projects into lessons learned at the program level
- To respond to growing interest among states implementing STEM initiatives for evidence-based replicable STEM education models
- To provide the community of practice with a dissemination tool to share lessons learned with the national community of STEM policymakers and practitioners
- To begin a more formal STEM learning exchange between the ITEST community and STEM practitioners nationally

The process began by identifying the essential elements commonly found in models describing educational programs. To begin exploring the degree to which models are emerging from the ITEST program, we translated those elements into a series of questions: What are the theoretical underpinnings of the emerging model? What is the theory of action? What are the intended outcomes? What are the program elements of the model that support the theory of action? What evidence is produced that supports the outcomes? (See Figure 1)

The 2011 Summit planning committee chose to organize that summit's program to support a common conversation among PIs who, at the end of the summit, would meet in working groups to propose specific areas in which ITEST models might be emerging. Of the areas proposed, our first selected for a "deep dive" was engineering. To support this exploration, new advisors were added to the LRC advisory committee with the goal of sharing their engineering content expertise by providing input and reviewing the emerging model, and then disseminating this model within their own networks. A two-day, intensive meeting was held in the summer of 2011; participants included seven representatives of six ITEST projects and an LRC advisor with engineering expertise. During the meeting, ITEST Engineering project leaders identified the program elements and outcomes they held in common, and discussed the evidence their projects were producing in support of those outcomes. The model presented in Figure 1 shares the output of that workshop.

The process of exploring emerging models is also providing the ITEST Engineering project community with opportunities to deepen content discussions with peers and advisors across projects. Throughout the process, members of the working group reviewed and discussed the theoretical foundations of ITEST and their projects, STEM content they hold in common, the intended and unintended outcomes of their projects, the various assessments they use to measure outcomes, and the degree to which they use common measures, as well as the evidence generated by their projects (both evidence that is formally reported to NSF and unreported evidence that is gathered and held in administrative records). Although not discussed in this report, the dialogue on assessments prompted a review and analysis of the constructs measured and assessments used by ITEST projects.

The ITEST Engineering Model presented in Figure 1 articulates the collective experience of the ITEST engineering projects. The findings reported below as evidence of claims are consistent with information reported in the recent ITEST Data Brief, which described results of the 2011–2012 ITEST Management Information System data-gathering efforts across the ITEST community. As the Engineering Model is shared nationally, the small engineering working group that developed the model will form the core of a larger ITEST engineering team ready to respond to solicitations for replicable, evidence-based STEM education models (e.g., Department of Education i3, Massachusetts' @Scale STEM Initiative) and ready to serve as mentors and guides to STEM stakeholders in states working to improve STEM learning through engineering initiatives in and out of school.

The supporting data included in this report was collected for the purpose of improving practice—it is not the result of randomized control trials or other experimental design studies using treatment and control groups. Therefore, statements implying causality must be interpreted with caution. However, the report does represent data that was faithfully collected and reported by the projects, through annual reports, external evaluator reports, and other publications, to document their successes and provide snapshots of the progress accomplished by project participants.

The ITEST program focuses on broad goals and encourages projects to move toward those goals in innovative ways. In turn, those innovations promote variation in how the projects articulate outcomes and collect data. Although we find that many projects hold similar outcomes in common, the absence of a common framework and measures makes it difficult to aggregate and appreciate lessons learned from the efforts of the ITEST community of practice.

Subsequent to our work with the Engineering Model Development group, a second working group of ITEST principal investigators and evaluators convened in June 2012 to explore and articulate ITEST's Workforce Education Model. They proposed a conceptual structure that organizes ITEST's workforce education outcomes in a way that can help organize data to better communicate ITEST's progress toward those outcomes the projects hold in common.

Using this conceptual structure as a backdrop, we hope to find the following as we move forward to explore ITEST's emerging models:

- More opportunities to use common assessments across the ITEST community
- A common framework to organize (1) the outcomes common to all of the ITEST projects (such as dispositions towards STEM content and STEM careers; knowledge of STEM content and STEM careers; skills in applying STEM content and STEM career skills; and actions that will increase the likelihood that youth will pursue STEM careers and/or STEM-enabled careers) and (2) the data supporting progress towards those outcomes
- More data on ITEST's STEM career outcomes
- Additional specifics on the ways projects address cultural context and the effects of the integration of cultural context on disposition, knowledge, skills, and action outcomes
- Further insight on partnerships and the effects of those partnerships on disposition, knowledge, skills, and action outcomes
- Additional information on the effects of teacher professional development on disposition, knowledge, skills, and action outcomes

We invite you to read this report to explore the ITEST Strategies projects, which have been testing tools, processes, and approaches to engineering education, and the ITEST Scale-Up projects, which have been spreading successful engineering education approaches, both in school and out of school, to new states and communities. The model, examples, and data included in this report are but a sampling of the many engineering education resources available from the ITEST Learning Resource Center. Whether you are a teacher, program administrator, or curriculum director, we offer this report to help you:

- Validate your own approach to engineering education by providing data on students engaged in similar educational experiences
- Frame presentations on engineering education for members of the local business community and school boards, other academic and educational partners, and STEM practitioners by offering a model that includes theoretical foundations, essential program elements, and evidence that supports engineering education claims
- Organize outcomes and data to position your own engineering education projects as replicable models within your community
- Augment local engineering education offerings by providing examples of innovative approaches that have been tested in ITEST projects
- Locate ITEST engineering projects in your community and state by including links to project websites as well as the ITEST LRC website, which includes a searchable database using key words (e.g., engineering, state
- Identify engineering education peers who are using the same tools, strategies, and/or approaches

We welcome your **questions and comments** on this report and invite you to **join** our National STEM (ITEST) Learning Exchange to connect with principal investigators, project staff, and other members of the ITEST community through webinars, online dialogs, and other learning exchange events.

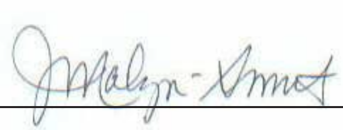

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Figure 1: ITEST Engineering Model

A Sampling of Theoretical Underpinnings

- Social Development Theory (Vygotsky, 1978)
- Social Cognitive Theory (Bandura, 1986)
- Social Cognitive Career Theory (Lent, Brown, & Hackett, 1994)
- Learning is an active process that integrates experience, interaction, and reflection (Dewey, 1933, 1938)
- Self-regulation (Zimmerman & Schunk, 2011; Pape, Zimmerman, & Pajares, 2002; Pintrich & de Groot, 1990)
- Engagement, capacity building, and continuity of learning (Campbell & Jolly, 2004)

Theory of Action:

Cumulative effect/interaction of essential elements of the ITEST Program lead to increased interest and engagement in and preparation for STEM careers.

Intended Outcomes

- Increased STEM learning
- Increased interest in STEM careers
- Increased engagement, motivation, and understanding of relevance to academics
- Increased understanding of work skills (skills needed for success in 21st-century workplaces)

ITEST Project Elements

- Focus on activities that motivate students to develop interest and skills in STEM careers
- Provide intensive engineering experience over a long duration
- Use technology tools and hands-on learning
- Involve industry mentors/scientists/engineers
- Incorporate students' self-regulated learning (self-directed learning) within specific engineering design experiences
- Offer innovative, high-interest STEM activities
- Involve participants in the designing and building of artifacts
- Use scientific investigation and/or the engineering design process
- Engage students in project-based and/or problem-based learning
- Develop participants' technical skills (as appropriate to the project)
- Make explicit connections between academics and project activities
- Build in success experiences and opportunities to learn from failure
- Exploration of technical careers from technicians to engineers and engineering management

A Sampling of Evidence

- ITEST youth demonstrated increased pre-/post- content knowledge and skills (LTED, 4-H, PL2, ITSI-SU, GreenFab)
- 4-H youth showed significant pre-/post- increases in interest in engineering and mathematics
- The percentage of BISU middle school students who indicated they were interested in the engineer job category doubled from the beginning to the end of the year
- GreenFab students outperformed their nonparticipating counterparts in the percentage passing the Regents test; these students also indicated increased learning in green tech, green design, and sustainable design
- ITSI-SU teachers showed a great increase in STEM career knowledge from summer to spring
- PL2 students go on to advanced or honors coursework in science and mathematics courses; the majority (80 percent) of PL2 graduates pursue STEM programs of studies, extended research, and leadership experiences

ITEST Engineering Model

Theory of Action: Cumulative effect/interaction of essential elements of the ITEST program lead to increased interest and engagement in and preparation for STEM careers.

A Sampling of ITEST's Theoretical Underpinnings:

- Social Development Theory (Vygotsky, 1978): ITEST youth more fully develop their cognitive abilities by engaging in experiences within their zone of proximal development guided through social interactions with scientists and other STEM professional and technical workers.
- Social Cognitive Theory (Bandura, 1986) and Bandura's work on Self-efficacy (1997): ITEST youth develop self-efficacy as STEM professionals, technicians, and technologists by modeling the behaviors of scientists and engineers solving problems.
- Social Cognitive Career Theory (Lent, Brown, & Hackett, 1994): Career choice is influenced by the beliefs the individual develops and refined through personal performance accomplishments such as ITEST success experiences.
- Learning is an active process that integrates experience, interaction, and reflection (Dewey, 1933, 1938). Engaging in the engineering design process promotes critical thinking, the application of technical knowledge, creativity, and an appreciation of the effects of a design on society and the environment (ITEA, 2000, 2002, 2007).
- Self-regulated learners are defined as "meta-cognitively, motivationally, and behaviorally active participants in their own learning" (Pape et al., 2002, p. 63; see also Zimmerman, 1989); self-regulation was also found to be one of the best predictors of academic performance (Pintrich & de Groot, 1990).

In addition to these theoretical foundations, numerous studies support the ITEST approach:

- The combination of engagement, capacity building, and continuity of learning is essential to progress in increasing students' interest in careers (Campbell, Jolly, & Perlman, 2004).
- The engineering design process promotes critical thinking, the application of technical knowledge, creativity, and an appreciation of the effects of a design on society and the environment (ITEA, 2000, 2002, 2007).
- Intense experiences of a long duration increase achievement (Dietel, 2009).
- Computers may help improve students' proficiency in mathematics and the overall learning environment (Wenglisky, 1998).
- Mentoring relationships "can offer significant rewards for the student through the contextualization of their learning and also through personal development" (Dutton, 2003, from **website abstract**). Contextualization helps students make connections between what they learn and their diverse life contexts (Imel, 2000).
- Matching of persons' interests with their environment leads to "greater satisfaction, performance, and persistence" (SWE-AWE-CASEE ARP Resources, 2008, from **website abstract**)
- Problem-based learning has been found to double the learning gains of the traditional lecture method (Yadav, Subedi, Lundeberg, & Bunting, 2011).
- Interconnectedness of STEM fields leads to increased motivation to "explore individual subjects in deeper ways" (Thornburg, 2008, p. 2).
- Constructive failure experiences, like those experienced as part of the iterative design process, can play an important role in classroom learning (Rhorkemper & Corno, 1988).

Elements of ITEST Engineering projects:

- Focus on activities that motivate students to develop interest and skills in STEM careers
- Provide intensive engineering experience of a long duration (academic year and/or summer, proportional to the nature of the project)
- Use technology tools and hands-on learning
- Involve industry mentors, scientists, and engineers
- Incorporate students' self-regulated learning (self-directed learning) within specific engineering design experiences
- Offer innovative, high-interest STEM activities
- Involve participants in the designing and building of artifacts
- Use scientific investigation and/or the engineering design process
- Engage students in project-based and/or problem-based learning
- Develop participants' technical skills (as appropriate to the project)
- Make explicit connections between academics (mathematics, science, and engineering activities) and project activities
- Build in success experiences and opportunities to learn from failure
- Exploration of technical careers from technicians to engineers and engineering management

Intended Outcomes & A Sampling of Supporting Data

Claim: Participation in ITEST engineering projects leads to increased interest in STEM careers

Supporting data:

- Eighty-three percent of Photonics Leaders 2 students identified a STEM-related career to pursue after college. (PL2)
- 4-H career interest camp data showed significant increases in youth interest in engineering and mathematics pretest to post-test. (4-H)
- The percentage of middle school students who indicated that they were interested in the engineer job category increased from 11 percent to 21 percent from pre- to post-implementation, doubled from the beginning to the end of project implementation, and increased from 34 percent to 42 percent among high school students in Build IT Underwater Robotics. (BIU)
- All Greenfab students thought that "making, designing, or inventing something" was moderately to very important at the end of the year, an increase from the beginning of the year. (Greenfab)
- Learning through Engineering Design (LTED) student-produced drawings show increased learning about engineering and engineers.
- The Digispired ii project had a great deal of success in increasing students' understanding of STEM principles and programming—knowledge of Scratch, electronics, C# and basic programming skills—associated with video games in both Years 1 and 2 of the project. (Digispired ii)

Claim: Participation in ITEST engineering projects leads to increased STEM learning

Supporting data:

- On average, students scored significantly higher on post-assessments than on pre-assessments for all units. (LTED)
- Results of the 2010 content tests for the camps show a significant increase from the Year 1 camp pretest to the post-test scores. (4-H)
- A review of pre-/post- knowledge test means indicates an increase in averages. (PL2)
- Mean class scores increased by almost 40 percent from pretest to post-test in the gears concept test, a highly significant increase; mean class scores for the buoyancy concept test increased by 33 percent from pre- to post-test, also a highly significant increase. (BIU)
- Greenfab students outperformed their nonparticipating counterparts in the percentage

who passed the Regents test. These students also indicated increased learning in green tech, green design, and sustainable design. (Greenfab)

- Students had a significant increase in the engineering post-assessment. (4-H)
- Fifty-two percent of students reported that they learned "a lot" or "a good amount" of the "Engineering Design Process." (Greenfab)
- Teachers showed a great increase in STEM career knowledge from summer to spring and a slight increase in interest in STEM careers. (Innovative Technology for Science Inquiry Scale-up Project, ITSI-SU)

Claim: Participation in ITEST Engineering projects leads to increased engagement, motivation, and understanding of relevance to academics

Supporting data:

- At least 65 percent of students in Cohorts I and II are taking advanced or honors mathematics courses; 72 percent of Cohort I students are taking advanced science courses; and 65 percent of Cohort II are taking honors science courses. (PL2)
- Eighty-seven percent of participants stated that the things learned in the program can be used in science class. (PL2)
- Eighty percent of PL2 graduates pursued STEM programs of studies, extended research, and leadership experiences. (PL2)
- PL2 students demonstrated an 80 percent retention rate . (PL2)
- Participants scored significantly higher on post-test attitude surveys that include measures of self-efficacy. (4-H)
- Middle school students who "liked science best" among all their classes (when the Build IT Underwater Robotics project was implemented in their class) increased from 44 percent to 50 percent, and the number of girls who "liked science best" increased from 40 percent to 58 percent. (BIU)
- Engineering design experiences increase students' ownership of learning: 52 percent of students report that they learned either a lot or a good amount about the engineering design process. (Greenfab)
- Digispired ii students were excited and eager to learn various topics at the trainings, which they believed were important for their lives now and in the future; students also enrolled in more STEM courses in 2011–2012 school year, compared to the previous year (2010–2011). (Digispired ii)

Claim: Participation in ITEST Engineering projects leads to increased understanding of Work Skills/ Engineering as a tool for 21st-century skills

Supporting data:

- There was a significant increase in youth's use of teamwork and problem-solving skills, two key competencies necessary for success in the 21st century. (4-H)

In addition to studies/reports referenced above, the ITEST Engineering Modeling team reviewed and offered into discussion evidence drawn from other project documents, reports, and research studies (Jenkins & Pell, 2006; Lowes & Lin, 2008; McGrath, Lowes, Lin & Sayres, 2009; Ganesh, 2010; Barker, Adamchuck, Grandgenett, & Nugent, 2011; Evaluation Resources, LLC, 2011; Reider 2011; Staudt & Zucker, 2011; Lewis Presser (n.d.)

Conclusion

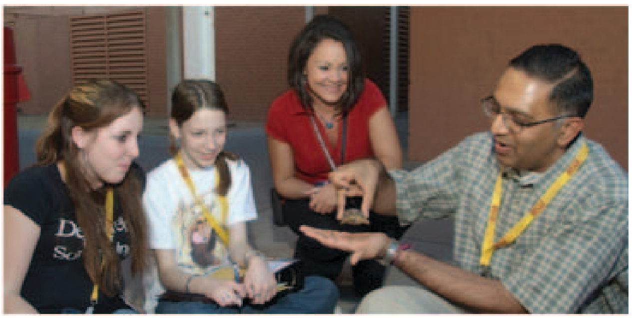
Feedback on the workshop experience indicates that the Engineering Model development team believes that their individual projects represent a collective ITEST engineering experience and that the ITEST Engineering Model is supported by the evidence they collect. The model framework was a useful way to collect and organize model elements across projects. Intense discussions with their ITEST colleagues helped participants learn about other projects and their shared challenges, and it made more visible other aspects that their projects have in common. The workshop additionally increased awareness that through their regular administrative and project management practices, projects are collecting more data than they are reporting in required reports. These data make valuable contributions to the ongoing work of developing ITEST models. The team noted that employing common measures and assessments across projects would be useful in generating data that more clearly reveal ITEST findings and the models emerging from the ITEST experience. Participants believed that the dialogue generated throughout the process helped them gain insights about the project evaluation process and think about their own projects in new ways. Overall, this contributed to their ongoing professional development and continual improvement of their own project work.

After the workshop, upon further reflection and follow-up conversations, it became clear that this work could have wider applications. Although the workshop content was focused on engineering education, many of the concepts that emerged apply to the other STEM disciplines represented in the ITEST portfolio and in the STEM education field in general. Furthermore, expanding the focus beyond content areas to other strands of ITEST that contribute to STEM career and workforce development will likely identify evidence of additional successful, replicable models of interest to the ITEST community, NSF, and the broader STEM education and workforce development fields.

Examples of ITEST Engineering Projects

Projects that Participated in the Engineering Model Workshop

1. Learning Through Engineering Design and Practice: Using Our Human Capital for an Equitable Future



Age/Grade:	Grades 7–9
Learning Environment:	Urban; out of school
Demographics:	Girls and minority youth
Location:	Phoenix, Arizona
Materials/ Technology/ Techniques:	Lego Robotics NXT kit [includes control unit, input sensors (touch, sound, distance, temperature, and light), two motors, four wheels, gears, connecting wires, axles, connectors, and a compilation of standard Lego pieces] Computer programming
Website:	**http://k12.engineering.asu.edu/**
Contributors/ Organizers/ Supporters:	Arizona State University, in collaboration with Arizona Science Center, Boeing, Intel, Microchip, Motorola, Salt River Project, Arizona Foundation for Resource Education, Arizona Game & Fish Department, US Partnership for the Decade of Education for Sustainable Development, Mesa Public Schools, Boys & Girls Clubs of the East Valley, National Science Foundation

In this extracurricular project youth in the greater Phoenix area use basic programming and robotics skills to solve technological design and engineering problems. Working in teams, the youth simulate desert tortoise behaviors, design solutions to mitigate the urban heat island of Phoenix and design human habitats for Mars.

2. Innovative Technology for Science Inquiry Scale-Up Project (ITSI-SU)

Age/Grade:	Grades 3–12
Learning Environment:	Rural, suburban, urban; in school
Demographics:	All
Location:	Kansas, Virginia, Alaska, and Iowa
Materials/ Technology/ Techniques:	Probeware Computational models
Website:	**http://itestlrc.edc.org/project_profile/innovative-technology-science-inquiry-scale-project-itsi-su** **http://www.concord.org/projects/itsi-su**
Contributors/ Organizers/ Supporters:	Concord Consortium, National Science Foundation

In this collaboration, over 1,500 middle and high school students participate in in-school activities that are designed to improve standards-based science instruction through a focus on guided student inquiry using probeware, computational models, and other interactive materials.

ITSI-SU teachers receive intensive teacher training and professional development over approximately 18 months (two school years and a summer). With access to sophisticated content through open-source software, teachers customize activities, develop standards-based units from ITSI-SU activities, and test them in their classrooms. The resulting observations and concrete achievements of students are shared back into what has become one of the largest collections of high-quality, online, technology-enabled science learning materials in existence.

Project goals address STEM workforce issues, examining how student learning, inquiry skills, and attitudes gained from the ITSI-SU program can positively influence students toward STEM content and careers.

3. GreenFab: Sustainable Design Through Engineering and Technology

Age/Grade:	High school
Learning Environment:	Urban; in school, out of school
Demographics:	Low-income, minority youth (some with disabilities)
Location:	South Bronx, New York
Materials/ Technology/ Techniques:	Mechanical and electrical engineering 3-D modeling Computer programming Sustainable design practice Professional design software programs
Website:	**http://www.bronxgreenfab.org**
Contributors/ Organizers/ Supporters:	Vision Education & Media, New York University's Interactive Telecommunications Program, The Bronx Guild High School, Sustainable South Bronx, National Science Foundation

GreenFab students develop the skills that support creativity and invention while gaining an understanding of how small-scale manufacturing can provide environmentally innovative solutions for a community's needs. GreenFab's enrichment program teaches STEM concepts through hands-on, project-based learning activities with an emphasis on career development in the emerging field of sustainable technologies. Over a three-year period, students attend a series of semester-length classes and after school sessions to learn and practice a variety of technology and engineering skill sets, including industrial design, sustainable practices, and prototyping.

The program takes place at Sustainable South Bronx's FabLab, an NSF-supported and MIT-designed fabrication laboratory. Students take several courses, including Engineering, GreenTech, and Sustainable Design, an applied design class. They learn to work independently through designing and executing a series of projects using real-world engineering tools in the FabLab, including computer information systems, physical computing, and engineering and design techniques. Alumnae are prepared to enter the 21st-century workforce with strong STEM skills and workplace-readiness.

4. National Robotics in 4-H: Workforce Skills for the 21st Century

Age/Grade:	Middle school
Learning Environment:	Rural; out of school
Demographics:	All, including girls and underrepresented populations
Location:	Nationwide (originated in Nebraska)
Materials/ Technology/ Techniques:	Educational robotics kit with programming software GPS/GIS technology
Website:	**http://www.gt21.org**
Contributors/ Organizers/ Supporters:	National 4-H Council, University of Nebraska-Lincoon 4-H Extension, the University of Nebraska at Omaha, National Science Foundation

Workforce Skills for the 21st Century expands a successful 4-H club-sponsored robotics program to approximately 4,800 students nationwide (ultimately representing 5 percent of the 4-H clubs in the United States). Led by informal educators (club leaders, afterschool educators, and parents), youth project teams at more than 480 sites learn technology skills, develop problem-solving abilities, and gain experience in teamwork. Attending summer camps and participating in annual 4-H robotics virtual competitions, student teams get hands-on experience with inquiry-based learning while addressing sophisticated robotics/GPS/GIS challenges.

The project has additional components for educators and for research. For educators, the program offers a professional development model to supplement adult volunteer skill sets and capacity. Participating educators gain experience and knowledge in online collaboration and social networking, while sharing students' achievements and techniques that work.

The research component explores how hands-on, inquiry-based robotics and GPS/GIS activities presented in an informal learning environment can effectively prepare youth for the STEM workforce. Questions examined include how educational robotics interventions positively impact youth STEM literacy and workforce skills, as well as how 4-H robotics curricula can help informal educators improve their STEM content knowledge, their teaching performance, and their confidence.

5. Photonics Leaders II (PL2)

Age/Grade:	Grades 10–11
Learning Environment:	Rural, urban; out of school
Demographics:	African American, Hispanic, and Native American students
Location:	North Carolina
Materials/ Technology/ Techniques:	Optics and electronics, including lasers, microscopes, digital cameras, and infrared communications Computer hardware and software
Website:	**http://itestlrc.edc.org/project_profile/photonics-leaders-ii** **http://www.science-house.org/index.php/about-photonics-leaders/curriculum**
Contributors/ Organizers/ Supporters:	North Carolina State University (NCSU) (researchers from Physics, Engineering, Distance Learning, and Education), The Science House (at NCSU), Research Triangle Park (industry leaders), National Science Foundation

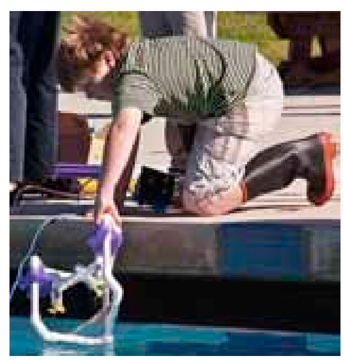
Using hybrid-learning environments at NCSU, 120 high school students and teachers discover the wonder of photonics through investigations into and internships involving electronics, optics, and laser technology. Content topics within the theme of photonics/optics include math, research design, information communication and technology, and career awareness and competency. Students gain hands-on experience with equipment, visit labs at the university and in industry, meet with NCSU and Research Triangle Park scientists, and conduct their own experiments and projects. In addition to scientific knowledge, the program supports student development of the intellectual, communication, and personal skills needed for success in the STEM workforce. Photonics Leaders II also empowers parents to be effective champions for students by offering information about college funding resources, college entrance requirements, and connections between coursework and career opportunities.

6. Build IT Underwater Robotics Scale Up for STEM Learning and Workforce Development (BISU)

Age/Grade:	K–12
Learning Environment:	Urban; both in school and out of school
Demographics:	Girls and underserved youth
Location:	Originated in New Jersey; expanding to Ohio, Illinois, and Texas
Materials/ Technology/ Techniques:	LEGO and Mindstorms equipment Social networking tools Webcasting technologies IT and cyberinfrastructure
Website:	**http://itestlrc.edc.org/project_profile/build-it-underwater-robotics-scale-stem-learning-and-workforce-development-bisu** **http://www.stevens.edu/news/content/exploring-science-through-underwater-robotics**
Contributors/ Organizers/ Supporters:	Stevens Institute of Technology; Center for Innovation in Engineering and Science Education; League for Innovation in the Community College, National Girls Collaborative Project, Texas Girls Collaborative Project at the University of Texas at Austin, Kentucky Girls STEM Collaborative at the University of Kentucky, Sinclair Community College in Dayton, Ohio, Triton College in River Grove, Illinois, National Science Foundation

This exciting program expands an underwater biotics project in New Jersey to three more states to bring engineering and science experiences to underrepresented communities. Students, particularly girls and underrepresented populations, work in teams and use LEGO and Mindstorms equipment to prototype, design, and program underwater robots. Their task: accomplish a series of "missions" in an 8-foot-diameter pool. Facilitated by trained educators, teams explore concepts such as design, buoyancy, stability, and gears to make robots that can swim, grab objects, and navigate obstacles.

Participants also develop interpersonal and technology skills as they learn to use social networking and webcasts to communicate with other teachers and students and to share what they've learned. Collaboration and problem-solving skills supplement the focus on career-capability in STEM-related fields.



As individuals and team members, students round out their experience by participating in an annual national virtual underwater robotics competition. On top of their increased knowledge and confidence, students also contribute to future learning opportunities for others by creating a cyber-learning community among youth, educators, and STEM researchers. All parties add to and benefit from the ongoing development of a digital video library providing anytime access to STEM and IT applications in the real world.

Other ITEST Engineering Project Profiles by Cohort

Cohort 4

7. Digispired: Digital Inspiration for Interactive Game Design and Programming Skills

Age/Grade:	Middle school
Learning Environment:	Rural, urban
Demographics:	Low-income
Location:	Virginia
Program Length:	144 hours of instruction over one year
Materials/ Technology/ Techniques:	Computer science—gaming and simulations, programming General skills and mathematics Multimedia—audio, video, and animation Engineering Robotics
Website:	**http://itestlrc.edc.org/project_profile/digispired-digital-inspiration-interactive-game-design-and-programming-skills** **http://www.digispired.org**
Contributors/ Organizers/ Supporters:	Longwood College, National Science Foundation

The Digispired (Digitally Inspired) project provides 90 urban and rural low-income middle school students with opportunities to learn computer programming, computer animation, and digital imaging. Students can put into practice what they're learning by creating games, with a focus on topics such as conservation and health, and by programming a LEGO robot.

Digispired students learn computer programming, computer animation, and digital imaging to create interactive games. They receive 144 hours of instruction per year (80 hours in the summer and at least 64 hours on Saturdays during the school year). Activities include exploring 3-D animation using Kahootz and Robolab, investigating the use of digital imaging and digital audio for game environments, and programming a LEGO robot.

Students focus on developing games to understand the importance of four major science topics: environmental conservation, health and nutrition, exercise and physical activity, and substance abuse. They develop logical thinking and enhance their programming skills by creating their own learning objects and interactive games. Parents participate in 60 hours of face-to-face workshops on such topics as using the Internet, conducting scholarship and financial aid searches, and understanding brain-based learning. All instructional and professional development resources developed by Digispired staff and at least 50 video games created by the students are available for download from the project website.

8. NSF ITEST (Launch-IT)

Age/Grade:	Grades 6–12
Learning Environment:	University campus; out of school
Demographics:	Underrepresented minorities, girls
Location:	Lehigh Valley, Pennsylvania—Lehigh University
Materials/ Technology/ Techniques:	Self-directed multimedia, e-learning materials; intelligent tutoring, and frequent mentoring by college undergraduate and graduate students.
Website:	**http://www.lehigh.edu/launchit/**
Contributors/ Organizers/ Supporters:	Binney and Smith, Air Products, PPL, Agere, Suntex, Lehigh University

Lehigh University proposes that the Launch-IT program (formerly named S.T.A.R.T.—Students That Are Ready for Technology) will promote academic achievement in information technology (IT) for at-risk middle and high school students in the Greater Lehigh Valley of Pennsylvania. Launch-IT will include summer and academic year programs on IT for students in grades 7–12. Launch-IT will build on successful curricula developed for the Lehigh Valley Partnership for Teaching Fellows, a National Science Foundation GK–12 project. Summer and year-round curricula will include programming remotely controlled mobile robots in a simulated Martian landscape (7th- and 8th-grade students), creating a Web-based music juke box using Macromedia Flash (9th- and 10th-grade students), and enhancing a "design-first" approach to learning Java (11th- and 12th-grade students) with the intent of preparing students for the Advanced Placement (AP) Computer Science test in two years. Math skills will be developed continually with the use of the Web-based 24 Game. The programs will include self-directed multimedia, intelligent tutoring, and frequent mentoring by college undergraduate and graduate students to encourage more girls and minorities to pursue computer science and enter the IT workforce. The Launch-IT program will be completely integrated into Lehigh's existing academic infrastructure, created for S.T.A.R., to ensure the new IT outreach activities are sustainable in the long term.

9. TechREACH

Age/Grade:	Middle and high school
Learning Environment:	Rural, out of school
Demographics:	Underserved populations
Location:	Eastern Washington
Program Length:	Engineering focus—one year
Materials/ Technology/ Techniques:	GIS/GPS Robotics Videogame programming 3-D modeling and animation software NSF-funded MESA *Real-World Mathematics Through Science* modules
Website:	**http://techreachclubs.org**
Contributors/ Organizers/ Supporters:	Washington State University MESA, Digipen Institute of Technology, Red Llama software company, National Science Foundation

In afterschool clubs and summer workshops supplemented with online e-mentoring, students and their teachers in six rural communities in Eastern Washington use GIS/GPS technology, robotics, and videogame programming to research local community issues.

Their focus over the three years is as follows:

	STEM Theme	**Local Issue**
Year 1	Robotics	The Washington apple industry
Year 2	Animation	Community design
Year 3	Video game programming	Renewable energy

Teachers, scientists, and other mentors guide youth as they develop their STEM skills and knowledge in both classroom and in-the-field settings. The program offers professional development for teachers and support for parents to help their children with college research and preparation.

Cohort 5

10. Detroit Area Pre-College Engineering Program (DAPCEP) Engineering and IT Project-C5

Age/Grade:	Grades 7–9
Learning Environment:	Urban; both in school, out of school
Demographics:	African American and Latino students
Location:	Detroit, Michigan
Program Length:	Varies
Materials/ Technology/ Techniques:	Varies
Website:	**http://www.dapcep.org**
Contributors/ Organizers/ Supporters:	DAPCEP, National Science Foundation

The mission of DAPCEP is to increase the number of historically underrepresented students who are motivated and prepared academically to pursue degrees leading to careers in STEM-related fields through K–12 supplemental educational programming. DAPCEP's engineering and IT project reaches more than120 underserved students in the Detroit area. Through a combination of in-school and off-site experiences, students use STEM tools and techniques to solve engineering and IT challenges. Parents and caregivers are involved in problem solving and support for children to explore college and career opportunities. Teachers and facilitators include scientists and engineers from college and corporate campuses—and students visit a variety of laboratories in both worlds.

11. Reach for the Sky: Integrating Technology into STEM Outcomes for American Indian Youth

Age/Grade:	Grades 5–12
Learning Environment:	Rural; in school, out of school
Demographics:	Native American students
Location:	White Earth Reservation, Minnesota
Program Length:	140 contact hours in summer and during school
Materials/ Technology/ Techniques:	Information technology STEM tools and techniques Traditional Native teaching systems
Website:	**http://rtfs.wordpress.com**
Contributors/ Organizers/ Supporters:	University of Minnesota (College of Food, Agricultural, and Natural Resource Sciences, College of Education and Human Development, and Institution of Technology, University of Minnesota Extension), White Earth 21st Century After School Program, schools on the White Earth Reservation (Circle of Life, Mahnomen, Pine Point, and Naytahwaush), National Science Foundation

Middle and high school Anishinabe students on the White Earth Reservation in Minnesota develop skills, knowledge, and interests in STEM and IT fields and deepen their understanding of energy and alternative energy sources through learning experiences that integrate STEM concepts with traditional Native teachings. School teachers, professors from tribal colleges and local universities, community elders, and out-of-school leaders facilitate lessons that integrate cultures and bodies of knowledge. Weaving traditional skills and knowledge with modern science has inspired and energized community involvement.

Cohort 6

12. FROM ART TO STEM—A Creative Journey of Discovery: A Transformational Project for Nashville Middle School Students

Age/Grade:	Grades 7 and 8
Learning Environment:	Urban; afterschool, informal
Demographics:	Girls from underrepresented populations
Location:	Nashville, TN
Materials/ Technology/ Techniques:	SPORE Creature Creator, Ford PAS, Google SketchUp, Alice, GoAnimate
Website:	**www.art2stem.org**
Contributors/ Organizers/ Supporters:	Metropolitan Nashville Public Schools (MNPS), PENCIL Foundation, Adventure Science Center, Tennessee Tech University, Alignment Nashville

Art2STEM (A2S) is designed to spark transformation in Nashville's middle school students by engaging them to participate in afterschool clubs. The goals of this project are to increase the enrollment of students in STEM-focused academies in high school and, ultimately, to impact Nashville's future workforce. A2S operates clubs in nine MNPS middle schools, with 215 recent enrollees. Club leaders are MNPS teachers and business professionals who volunteer their time to serve as coaches. The A2S coaches help girls in grades 7–8 build on their interests in art and other, more traditional careers and guide them through carefully planned activities that create a new awareness of how those interests converge with STEM (coaches receive extensive professional development during the summer and over the school year). Complementing the club meetings, real-world connections are made through site visits—field trips—to local companies and higher education institutions where girls can meet and interact with female STEM professionals.

A2S explores answers to two fundamental questions the ITEST program seeks to address: (1) How do students acquire the knowledge, skills, and dispositions they need in order to participate productively in the changing STEM workforce? and (2) How can we assess and predict students' inclination to participate in the STEM fields? By incorporating insights and successful practices arising from the study *How People Learn*[1] and specific experiences and expertise of the Nashville educational community, A2S aims to accomplish the following:

- Provide meaningful and rigorous experiences for students that highlight the relationship between art and STEM

1. Committee on Developments in the Science of Learning, & Committee on Learning Research and Educational Practice, National Research Council. (2000). *How people learn: Brain, mind, experience, and school.* Washington, DC: National Academies Press.

- Align with the standards of MNPS
- Be relevant to the skills of successful STEM professionals
- Connect girls' creative interests to STEM-related projects and activities and subsequently to opportunities in the STEM workforce where they can make a difference
- Integrate multiple approaches rather than relying on a single event or strategy to impact the perceptions the girls have of STEM and STEM-related careers and professionals
- Allow girls to develop, observe, and practice 21st-century skills
- Create a vision and awareness of pathways leading to STEM-related careers

While A2S is a response to education innovation at this particular juncture for Nashville and MNPS, the practices can be adopted and adapted by other communities to meet their unique situations.

13. High School Enterprise

Age/Grade:	Grades 9–12
Learning Environment:	Urban, suburban, rural; out of school
Demographics:	All income levels; underrepresented populations
Location:	Georgia, Illinois, Michigan, Puerto Rico
Program Length:	Varies
Materials/ Technology/ Techniques:	Varies
Website:	**http://www.enterprise.mtu.edu/highschool/**
Contributors/ Organizers/ Supporters:	High School Enterprise teams, American Society of Mechanical Engineers, National Science Foundation, Michigan Tech

High School Enterprise (HSE) teams form virtual companies who work with local businesses to develop products or to design solutions that solve real-world problems. Teams and their local business clients tackle STEM- and information and communication technology-based challenges as they design and create their products for distribution in the marketplace. Teams manage the design process as well as budgets, deadlines, and delivery of their products or solutions. At the end of the school year, teams showcase their products as presentations at Michigan Tech's Undergraduate Expo. Through this process, students begin to think and feel like professionals, taking charge of their own education. As an afterschool program, HSE gets students out of the classroom and into teams—giving them a chance to manage long-term projects from inception to completion.

14. MarineTech: STEM Preparation Through Marine Engineering, Science, and Technology Experiences—Collaborative Research

Age/Grade:	Grades 8–12
Learning Environment:	Urban; out of school
Demographics:	All
Location:	Norfolk, Virginia
Program Length:	Eight Saturdays during the academic year; two-week summer academies per year, including field trips and externships
Materials/ Technology/ Techniques:	Marine kits Sea Perch Robot kits Human-Powered Container Ship kits
Website:	**http://www.themarinetech.org/**
Contributors/ Organizers/ Supporters:	Old Dominion University, Norfolk State University, Longwood University, National Science Foundation

In Norfolk, Virginia, students and teachers in grades 8–12 engage in hands-on learning experiences in the fields of marine engineering, physical sciences, and robotics with a shipbuilding focus on underwater and above-water vehicles. Students participate in field trips and externships to explore Sea Perch robotics, ship design, shipbuilding, shipyard operations, and ship disaster investigation. MarineTech's goals are bold: boost student scores on STEM academic achievement in marine engineering, physical science, and information technology, and ultimately help address the critical shortage of qualified workers needed to sustain America's shipbuilding and ship repair industry.

The MarineTech curriculum aligns with both state and national technology education, math, and science standards. For teachers, there is a training component offering 16 hours of summer professional development and 20 hours of follow-up support each year. To date, 60 students and 60 teachers have participated, working with university professors and shipbuilding industry professionals to solve sophisticated engineering challenges and participate in the end-of-year showcase and competition.

Cohort 7

15. Beyond Blackboards: Integrated Methods for STEM Education and Workforce Development

Age/Grade:	Middle school
Learning Environment:	Urban, after school
Demographics:	Underrepresented and economically disadvantaged students
Location:	Austin, Texas
Program Length:	Varies
Materials/ Technology/ Techniques:	Robotics Information and communication technology (ICT)
Website:	**http://itestlrc.edc.org/project_profile/beyond-blackboards-integrated-methods-stem-education-and-workforce-development**
Contributors/ Organizers/ Supporters:	University of Texas Cockrell School of Engineering, DTeach, Skillpoint Alliance, Round Rock Independent School District, National Science Foundation

Beyond Blackboards expands narrow definitions and preconceptions of engineering by challenging participants to answer the question, "What is an engineer?" The program emphasizes hands-on experience with technology (such as designing a hand-crank flashlight) and the use of design challenges and robotics to create a context for math and science learning. Not only do students benefit, the program also targets teachers, school administrators, and parents and caregivers, increasing each participant's knowledge of the wide range of career opportunities available to strong math and science students.

Students work in teams after school and during the summer to study STEM topics and build robotics projects together. Focusing on Grand Challenges in Engineering, students build skills in analysis, problem-solving, negotiation, creativity, tolerance for ambiguity, and understanding of systems thinking.

Since raising a STEM scientist requires a village, this program also includes comprehensive programming for all who touch the lives of students:

- Teacher training and professional development for teachers
- Training for school counselors, administrators, and other educators
- Outreach to caregivers

The program goal is to support students to pursue careers in ICT and STEM-related fields, although the skills learned can support them in successfully pursuing university degrees and lucrative career paths in any number of fields.

16. CAPSULE: CAPStone Unique Learning Experience

Age/Grade:	High school
Learning Environment:	Urban, out of school
Demographics:	All
Location:	Massachusetts
Program Length:	Varies
Materials/ Technology/ Techniques:	Varies
Website:	**http://itestlrc.edc.org/project_profile/capsule-capstone-unique-learning-experience** **http://www.stem.neu.edu/capsule.htm**
Contributors/ Organizers/ Supporters:	Boston Public Schools, Northeastern University engineering research centers and the STEM Education Center, Boston Museum of Science, National Science Foundation

CAPSULE, a capstone project-based learning model, brings STEM and IT workforce experiences to life by introducing students to the real world of corporate industry. Students begin with materials developed at the Museum of Science and are then assigned actual problems from local industry, from which they formulate and conduct their own projects. In the process, students apply STEM concepts from the classroom to the engineering design process. They also produce their own media content for their projects. Students visit companies to learn firsthand about the day-to-day activities of the STEM and IT workforce.

CAPSULE includes a teacher training component comprising a two-week summer professional development workshop with follow-up during the year for a total of 120 hours. Activities are available for school administrators, guidance counselors, and parents to make them aware of the value and importance of STEM and IT careers and opportunities.

17. Creating College Pathways through Application of Technology to Explore Urban Ecological Challenges (or Social justice for Talented Emerging Minds—SjTEM)

Age/Grade:	Grades 9—12
Learning Environment:	Urban
Demographics:	Minority
Materials/ Technology/ Techniques:	GIS, GPS, field work, data visualization, computer modeling, interdisciplinary science, career coaching
Website:	**http://urbaneco.bc.edu**
Contributors/ Organizers/ Supporters:	College Bound Program at Boston College in collaboration with Boston Public Schools; Placeways, LLC.; Urban Ecology Institute; Madison Park Community Development Corporation; and DeRosa Environmental Consulting

This Social Justice for Talented Emerging Minds program, or SjTEM, is designed to improve the scientific and mathematical skills of urban youth and to empower them to solve social and environmental justice challenges in their neighborhoods. We recruit urban youth in 9th grade and engage them in our program through 12th grade. (Those who go on to attend college will in most cases represent the first generation in their families to do so.) While in the program, youth receive mentoring and interact with professionals in STEM career fields.

Youth in our program learn how to use a geographic information system (GIS), which, when coupled with computer modeling, allows them to create and evaluate urban plans for vacant lots in the city of Boston. They conduct this work in collaboration with a local community development corporation and an environmental consulting firm. Using the GIS, youth estimate the ecological and economic impacts of their plans on their neighborhoods. (Recently, certain aspects of the youths' plans were integrated into a proposal for the redevelopment of a vacant lot; the proposal was accepted as the winning design by the city of Boston.)

As they explored the social justice issues in their neighborhoods, students created GIS-based resource maps of their neighborhoods. In doing so, they learned that the areas in which they live do not have equal access to healthy and affordable food when compared to other areas in Boston. Students found that, in many cases, it takes at least two bus transfers and sometimes an additional train ride to get to the nearest full-service grocery store. As a solution, the students proposed that farmers markets be created in areas lacking a supermarket. To help achieve this goal, they are building vertical hydroponic systems and setting up a youth-run market in their own neighborhoods to improve residents' access to fresh, affordable, and healthy food.

18. Digispired ii: Workforce Investigation Inspiration for STEM (WiiforSTEM)

Age/Grade:	High school
Learning Environment:	Urban, rural; out of school
Demographics:	Low-income youth
Location:	Virginia
Program Length:	144 hours face-to-face (two weeks and summer; at least 8 Saturdays)
Materials/ Technology/ Techniques:	Digispired ii: Scratch, Microsoft Visual C# 2010 Express, Unity 3D, Arduino, Picoboard, LilyPad Arduino, Discover Electronics kit, and other consumable resources, such as Universal remote and graphing calculators
Website:	**http://itestlrc.edc.org/project_profile/digispired-ii-workforce-investigation-inspiration-stem-wiistem**
Contributors/ Organizers/ Supporters:	Longwood University, Longwood Institute for Teaching through Technology & Innovative Practices (Contributor and Organizer), Virginia State University, Georgia Gwinnet College , Edvantia (Contributors), Old Dominion University, Southern Virginia Higher Education Center, Riverstone Energy Center, Mid-Atlantic Maritime Academy, Old Dominion University, University of North Carolina at Chapel Hill (field trips about college admission), National Science Foundation

A team of researchers, technologists, engineers, and computer scientists from Longwood University, Longwood Institute for Teaching through Technology & Innovative Practices (ITTIP), Virginia State University, and Georgia Gwinnet College have designed and are implementing the ITEST Strategies project *"Digispired ii: Workforce Investigation Inspiration for STEM (WiiSTEM)."* Instead of using games created by others or creating simple games like those of Digispired, Digispired ii is unique and innovative in inspiring 60 high school students to investigate mathematics, science, and engineering principles related to the use of game controllers (such as kinematics and kinesthetic) and to create games using a professional game authoring system. Twenty-five of these 60 students also partici-pated in Digispired, which provides the PIs an opportunity to study the longitudinal impact of an ITEST project on students. Digispired ii students used the Discover Electronics kit to understand engineering design concepts. They also used microcontrollers such as Arduino and Picoboard in Scratch games; participated in LEGO robotics, Vex robotics, and underwater robotics activities, during the project and on their own; developed programming skills with C#, and interacted with scientists, game designers, and engineers at university campuses, on field trips to industries, and during visits to hands-on science centers. Seven Digispired ii students have been accepted in math and science or engineering specialty centers or in Governor's Schools; eight students participate in STEM challenges or game design challenges every year; and four students with autism have shown greater interest in pursuing computer science or computer graphics for their choice of college major. Students are continuing to learn about game design with Unity, a game development engine, and about design process using LilyPad Arduino. In order to sustain the project after the funding period, Longwood University is preparing teachers to use Scratch in K–12 classrooms and disseminating research findings on effective instructional strategies in STEM classrooms.

19. Innovative Flight Simulation Experiences for Students and Teachers

Age/Grade:	Grades 8–12
Learning Environment:	Rural, out of school
Demographics:	All
Location:	Macon County, Alabama
Program Length:	Varies
Materials/ Technology/ Techniques:	Varies Flight simulators
Website:	**http://itestlrc.edc.org/project_profile/innovative-flight-simulation-experiences-students-and-teachers**
Contributors/ Organizers/ Supporters:	Tuskegee University (Aerospace Science Engineering, Mathematics, and Psychology & Sociology Departments), National Science Foundation

For youth, who are so often fascinated by flight, this program uses the flight simulation experience as an entrée to physics and mathematics learning. Students participate in a low-cost flight simulation environment at Tuskegee University, supported by classes and hands-on activities. The content is organized and delivered in modules, introducing concepts of physics and mathematics and their inter-relationship and application in real life. Engineers and scientists from Tuskegee University, famous for its rich heritage of the Tuskegee Airmen, engage students and teachers in discussion and activity. Students work in teams to produce a final project.

20. MATE ROV Competitions: Providing Pathways to the Ocean STEM Workforce

Age/Grade:	Middle school
Learning Environment:	Urban, suburban, rural; out of school
Demographics:	Underrepresented groups
Location:	Nationwide
Program Length:	Varies
Materials/ Technology/ Techniques:	Remotely operated vehicle robotics
Website:	**http://www.materover.org/main/**
Contributors/ Organizers/ Supporters:	Marine Advanced Technology Education (MATE) Center, National Science Foundation

This project uses the MATE Center's annual underwater robotics (remotely operated vehicle, or ROV) competition as an engaging platform to prepare middle and high school students for careers in the ocean STEM workforce. Middle and high school students gain technical skills while developing skills in problem solving and critical thinking. In teams, they make engineering presentations, design underwater ROVs to carry out specific missions or tasks, write technical reports, and create poster displays. Competition preparation includes coursework in four curriculum modules, field trips to meet industry professionals in the workplace, and team working sessions. The MATE competition reaches more than 2,400 students and 240 teachers.

The program provides teacher training, a website with information for students and parents on career information, and a cyberlearning center that uses web technologies and social media tools to engage and increase the number of users accessing and sharing information, resources, and ideas. Parents are encouraged to participate in project activities and to access the online resources.

21. PURSE: Promoting Underrepresented Girls' Involvement in Research, Science, and Energy

Age/Grade:	Grades 9–11
Learning Environment:	Urban; out of school
Demographics:	Girls
Location:	Detroit, Michigan
Program Length:	Varies
Materials/ Technology/ Techniques:	Renewable energy technologies
Website:	**http://itestlrc.edc.org/project_profile/purse-promoting-underrepresented-girls-involvement-research-science-and-energy**
Contributors/ Organizers/ Supporters:	Detroit Area Pre-College Engineering Program Inc., National Science Foundation

Through their involvement in PURSE, girls develop STEM skills through project-based, out-of-school-time space and engineering activities focusing on the production and storage of energy. Students study key mathematical and scientific concepts in such areas of energy as batteries and fuel cells; nuclear energy; and alternative energy sources, including wind and solar. In teams, girls produce a final project that integrates fundamental chemistry, physics, and engineering concepts around energy generation and storage. Experiences are multi-layered and engaging, motivating girls' passion and encouraging them to explore leadership in the renewable energy and energy efficiency industries.

22. Science, Engineering, and Technology for Students, Educators, and Parents

Age/Grade:	Grades K–3
Learning Environment:	Urban; in school, out of school
Demographics:	African American and Hispanic students
Location:	Chicago, Illinois
Program Length:	Four years
Materials/ Technology/ Techniques:	Digital technologies
Website:	**http://itestlrc.edc.org/project_profile/science-engineering-and-technology-students-educators-and-parents**
Contributors/ Organizers/ Supporters:	Chicago Pre-College Science and Engineering Program Inc., Museum of Science and Industry, J.P. Morgan Chase Bank, Mercy Hospital, Illinois Institute of Technology, National Science Foundation

To instill excitement for STEM topics, this program reaches out to young children and their parents with hands-on, activity-based instruction in science, engineering, and digital technology. Science, Engineering, and Technology for Students, Educators, and Parents (SETSEP) exposes participants to a range of science content and technologies while fostering an awareness of STEM careers. Students visit institutions and companies in the community and engage with engineers and scientists, learning to explore resources that spark their interest in STEM ideas and activities.

SETSEP asks participants, including parents, to commit to the full four-year program. SETSEP also empowers parents with tools and resources to support their children. Thirty teachers from seven Chicago public schools participate and receive ongoing professional development.

Grade	Focus
Kindergarten	Little Hydrologist
Grade 1	Little Chemist
Grade 2	Little Electrical Engineer
Grade 3	Little Mechanical Engineer

Cohort 8

23. Design Loft STEM Learning Program

Age/Grade:	Middle school
Learning Environment:	Out of school
Demographics:	Underserved students
Location:	California
Program Length:	Varies
Materials/ Technology/ Techniques:	Sustainable energy technologies
Website:	**http://itestlrc.edc.org/project_profile/design-loft-stem-learning-program**
Contributors/ Organizers/ Supporters:	Stanford University, National Science Foundation

Design Loft challenges students to use "design thinking" to solve real-world problems of impoverished people around the world. In the Design Loft STEM Learning Program, students design low-cost engineering solutions to improve poor people's access to water, shelter, and energy. During intersession career camps, students learn design thinking through exploring energy and renewable resources technology and engineering concepts.

For teachers and camp educators, the program offers a professional community institute, a website, instructional resources, and a scalable model for implementation. Students learn the practicalities of pursuing a STEM-related career and have access to a participant-mentoring course for STEM college students.

24. Middle School Science Readiness Program

Age/Grade:	Elementary to middle school
Learning Environment:	Urban; out of school
Demographics:	All
Location:	Houston, Texas
Program Length:	One school year
Materials/ Technology/ Techniques:	Varies
Website:	**http://itestlrc.edc.org/project_profile/middle-school-science-readiness-program**
Contributors/ Organizers/ Supporters:	Houston Independent School District, Baylor College of Medicine, NASA–Johnson Space Center, Texas Medical Center, National Science Foundation

Targeting the critical drop-off point between elementary and middle school, this program supports science teaching and learning for at-risk students. Taking place after school, the Middle School Science Readiness Program offers classes and activities for 320 students and 16 teachers at elementary schools in Houston, Texas. The goal is to interest, motivate, and engage students and to help them through this transition, often seen as the first major roadblock to success and interest in STEM content. Activities include participation in real-world STEM fields, such as aerospace (NASA–Johnson Space Center), energy (petrochemical industry), and biotechnology (Texas Medical Center).

The program content has been developed by an interdisciplinary project team, including university faculty members, scientists, an educational psychologist, data managers, online education providers, principals, teacher leaders, and parents. Topics include language and social skills that support career awareness in STEM-related fields.

25. NanoExperiences: Pathways to Workforce Success

Age/Grade:	High school
Learning Environment:	Urban; out of school
Demographics:	All
Location:	Colorado
Program Length:	One year
Materials/ Technology/ Techniques:	Nanoscale science and technology (NS&T) NanoExperiences toolkit
Website:	**http://itestlrc.edc.org/project_profile/nanoexperiences-pathways-workforce-success**
Contributors/ Organizers/ Supporters:	Colorado Community College System, Mid-Continent Research for Education and Learning, National Science Foundation

NanoExperiences focuses specifically on high school students who are preparing for postsecondary education and who are particularly interested in careers in NS&T. The curriculum includes coursework, field trips, and hands-on projects. The first semester focuses on NS&T concepts, tools, and instrumentation and includes an exploration of NS&T occupations and societal implications through large-group meetings, projects, and both real and virtual presentations by professionals in NS&T industries. Over the summer, students visit nanoscale businesses and develop their final project plans. During the fall, students develop and execute their final projects and present their work in a final symposium.

26. Society's Grand Challenges in Engineering as a Context for Middle School Instruction in STEM

Age/Grade:	Middle school
Learning Environment:	Urban, rural; in school
Demographics:	Open to all, particularly girls
Location:	Wisconsin
Program Length:	Varies
Materials/ Technology/ Techniques:	Varies
Website:	**http://itestlrc.edc.org/project_profile/societys-grand-challenges-engineering-context-middle-school-instruction-stem**
Contributors/ Organizers/ Supporters:	University of Wisconsin–Madison, National Science Foundation

This in-school program integrates STEM-focused instruction into middle school curricula to inspire and attract students. It is based on three instructional modules that meet curricular standards and build on challenges identified in the National Academy of Engineering's "Grand Challenges for Engineering in the 21st Century." Students are challenged to address human needs of global proportion (e.g., energy, health care, infrastructure, safe food, clean water) through engineering solutions.

Designed by a project team of university faculty (from engineering and education), middle school teachers, and guidance counselors, the program also offers training to teachers implementing the modules. Students who participate are measured for levels of STEM career interest, math and science self-efficacy and outcomes expectations, and exploration of STEM careers and study, in comparison to a control group of non-participating students.

27. The FabLab Classroom: Preparing Students for the Next Industrial Revolution

Age/Grade:	Grades 4–5
Learning Environment:	Suburban, out of school
Demographics:	All
Location:	Virginia, Texas
Program Length:	Varies
Materials/ Technology/ Techniques:	Classroom FabLab, a computer-controlled manufacturing unit 3-D computer modeling Manufacturing design processes Online Digital Fabrication Library
Website:	**http://itestlrc.edc.org/project_profile/fablab-classroom-preparing-students-next-industrial-revolution**
Contributors/ Organizers/ Supporters:	University of Virginia, University of North Texas, Cornell University, FableVision, Peggy Healy Stearns, Hofstra University, The Society for Information Technology and Teacher Education, National Science Foundation

The FabLab Classroom brings to life the world of engineering design and the associated mathematics that make personal fabrication of imagined ideas possible. Using manufacturing design processes and digital fabrication, students create physical models and put mathematical concepts into a real-life context. In practice, students design three-dimensional objects on a computer. They then have them built by the FabLab, a computer-controlled manufacturing unit adapted from more complex machinery for use in elementary schools.

The program is a collaboration of many parties: Cornell University, for the FabLab; the University of Virginia and the University of North Texasm, for prepping teachers in personal fabrication; FableVision and Peggy Healy Stearns, for the software; the University of Virginia and Hofstra University, for the curriculum; and The Society for Information Technology and Teacher Education, for an online Digital Fabrication Library to house the curriculum, activities, and digital designs. The project integrates the fields of mathematics and engineering education through the FabLab, curriculum, and professional development, ultimately offering an evaluated model to other educators around the country.

28. The Robot Algebra Project

Age/Grade:	Middle school
Learning Environment:	Formal and informal education
Demographics:	All
Location:	South Western Pennsylvania
Materials/ Technology/ Techniques:	Robotics, 9797 LEGO Education NXT Set, LEGO MIINDSTORMS NXT Programming Software
Website:	**http://www.cs2n.org/activities/robots-in-motion**
Contributors/ Organizers/ Supporters:	Carnegie Mellon Robotics Academy, the University of Pittsburgh's Learning Research and Development Center, LEGO Education North America

The Robot Algebra Project created three scalable, middle school-level units for use in informal settings. The units are designed around fundamental robot movement concepts and emphasize proportional reasoning—a big idea in mathematics. There are over 14,000 FIRST Lego League teams across the United States that purport to use robots as a motivator to engage students in STEM. However, most of the time, the students use guess-and-check procedures, thereby thwarting the opportunity to learn STEM content.

The units, which are under development, build upon model-eliciting activities, project-based learning, and mathematics education to improve student understanding of a specific key mathematics concepts. The programming of robots is scaffolded so that students concentrate on the mathematics. Rather than only doing hands-on activities, the students also produce toolkits for other students to engage in similar experiments. Paper-based word problems are used to connect the mathematics that students learn in the context of robotics to generalized mathematical problem-solving strategies. Professional development is provided both face-to-face and through webinars to early adopters, who are also trained to provide professional development to others. Supplemental materials to the professional development support teachers and informal educators in understanding the rationale, agenda, mathematics, and perspectives underlying the student materials and in anticipating student responses to the tasks. The materials can be updated online.

Cohort 9

29. Maximizing Mentor Effectiveness in Increasing Student Interest and Success in STEM: An Empirical Approach Employing Robotics Education—Collaborative Research

Age/Grade:	Middle school
Learning Environment:	Suburban; out of school
Demographics:	Underrepresented and non-underrepresented students in STEM
Location:	Illinois
Program Length:	Varies
Materials/ Technology/ Techniques:	Robotics
Website:	**http://itestlrc.edc.org/project_profile/maximizing-mentor-effectiveness-increasing-student-interest-and-success-stem-empiric**
Contributors/ Organizers/ Supporters:	University of Southern California, Southern Illinois University at Edwardsville, National Science Foundation

As a pathway to encouraging underrepresented students in STEM, this project studies the best methods for mentoring students who had not previously enrolled in robotics activities. Student teams of approximately 10 each (mixed boys and girls) compete in a Botball regional robotics competition organized by the KISS Institute for Practical Robotics. Each is assigned a team mentor.

Research questions include How do people make achievement-related choices when deciding what areas to study and what careers to pursue? and How can mentoring influence those choices? The project examines three types of mentor training (best-practices mentor training, self-efficacy mentor training, a combination) compared with no mentor training for their impact on STEM self-efficacy and expectations of success and/or STEM achievement-related choices. The results, along with feedback from mentors, are being used to develop a mentor-training package that embodies the most effective components of mentoring for underrepresented and non-underrepresented students in robotics and other STEM programs.

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