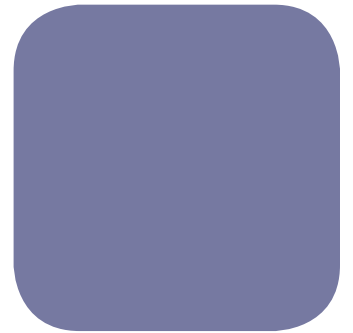


**Preparing Tomorrow's
STEM Workforce Through
Innovative Technology
Experiences for Students
and Teachers**



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Preface

Joyce Malyn-Smith, Siobhan Bredin, and Suzanne Reynolds-Alpert

ITEST: Taking Stock, Moving Forward

The ITEST (Innovative Technology Experiences for Students and Teachers) Program, now in its seventh year of funding through the National Science Foundation (NSF), is pleased to present *Preparing Tomorrow's STEM Workforce through Innovative Technology Experiences for Students and Teachers*. This report is a product of the ITEST Learning Resource Center (LRC). It contains a series of six articles that explore critical issues and pose questions that have emerged from the work of more than 160 ITEST projects. Each article highlights key aspects of STEM (science, technology, engineering, and mathematics) education, workforce development, research, or practice. All are illustrated with innovative technology experiences drawn from ITEST project participants.

Article authors are ITEST LRC Principal Investigators (PIs), team members, or partners who share current thinking on relevant topics, reflect on the literature in their fields of expertise, and connect these to ITEST project activities and learnings. They also present the community's progress and perspectives as viewed through the lens of the following six themes central to STEM education:

- Workforce development
- Equity and diversity
- Informal learning
- Teacher professional development
- Evaluation capacity building
- The ITEST community of practice

In “ITEST and Workforce Development,” ITEST LRC PI Joyce Malyn-Smith reviews our national efforts to articulate the essential skills necessary for workplace success. She shows how ITEST projects support current thinking on the abilities needed for achievement in what is widely recognized as an “innovation economy.” Malyn-Smith shares insights garnered from the collective experience of ITEST projects that are investigating what youth know and are able to do with technology. She also reflects on the aspects of ITEST that might motivate youth—particularly those from groups traditionally underrepresented in STEM fields—to pursue STEM careers. In closing, she challenges the ITEST community to be strategic about collecting and storing data that describe the innovative STEM experiences of students and teachers, so that a growing database will contain authentic and comprehensive data that can be quickly disseminated to inform policy and practice in STEM education and workforce development.

Diversity sparks creativity and ingenuity, essential elements in building a workforce to support an innovation economy. In “Equity and Diversity,” ITEST LRC co-PI Sarita Pillai discusses how ITEST's approaches to motivating youth can be used as guidelines for developing and sustaining STEM talent in our underrepresented communities—contributing to a robust, well diversified STEM workforce. Pillai describes how ITEST projects are using effective strategies to engage youth from populations underrepresented in STEM and to foster their persistence in STEM fields. She suggests that new research focus on distinctions among sub-populations of youth.

Out-of-school time is fertile ground for STEM learning. The “Informal Learning” article, authored by ITEST LRC co-PI Tony Streit and Wendy Rivenburgh, asks the afterschool field to leverage its experience to address STEM education and workforce development issues. Streit and Rivenburgh reflect on the state of the afterschool field with regard to STEM. They profile an array of ITEST projects that serve as good illustrations of afterschool STEM learning, and they discuss ways in which ITEST projects demonstrate the power of blending the best of formal and informal learning. Looking forward, they identify questions that the ITEST community is poised to help answer around the role of the afterschool community in supporting STEM.

Teacher professional development is key to ensuring students’ interest in STEM-related courses and their success in moving through the STEM pipeline. In “ITEST Teacher Professional Development: Distinctive Implementation of Best Practices,” ITEST LRC co-PI Caroline Parker and co-authors Cathlyn Stylinski, Carla McAuliffe, Marjorie Darrah, Preeti Gupta, and Bercem Akbayin share the results of an exploratory study that revealed the professional development components most important to ITEST project PIs. They highlight the distinctive ways that ITEST projects provide innovative STEM professional development to teachers. They also discuss six successful strategies used by ITEST projects to build the capacity of teachers to bring IT into the classroom. Parker and her team underscore the vital contribution ITEST is making to the field. ITEST projects are generating new data on the efficacy of two innovative strategies— involvement of students and an emphasis on STEM career connections. The latter is a component rarely found in STEM professional development and appears to have significant potential to support transformations in STEM teaching and learning.

Evaluation is necessary to gain an understanding about what works and how, as well as to establish the effectiveness of programs or interventions. In “ITEST Evaluation: It’s About Building Capacity,” ITEST team member Leslie Goodyear discusses the evaluation capacity building (ECB) work of the ITEST LRC, and through two project examples describes ways in

which ITEST projects developed evaluation capacity. The SPIRIT project worked very closely with their evaluator to generate data to guide project decision-making and to demonstrate project outcomes. The Technology at the Crossroads project participated in an LRC-facilitated research working group that brought capacity and knowledge back to their project work. Goodyear concludes by posing three questions that continued research on evaluation capacity building in the ITEST community can address.

In “The ITEST Community of Practice: Lessons and Implications,” ITEST LRC co-PI and Project Director Siobhan Bredin and Ardice Hartry, LRC’s project evaluator, describe the community of practice (COP) that has emerged among ITEST project PIs and teams and the elements that keep the community participants engaged. ITEST’s COP includes the LRC, NSF program officers, the PIs and staff of funded projects, partners, and other key stakeholders who share their knowledge and experiences through conference calls, online discussions, webcasts, and annual meetings; and collaborate on conference presentations, articles, and research in small groups. Bredin and Hartry discuss lessons learned from the ITEST experience that can inform the work of others seeking to develop COPs. They close by noting how the identified strategies contribute to ongoing program improvement and support the field of STEM education and workforce development. The strategies raise new questions that help us gain deeper insights into how the COP has contributed to—and can continue to contribute to—the ITEST Program as it evolves and matures.

Strides Toward Sustainability: Snapshot of the Role and Impact of the ITEST Community of Practice

This report, like many other publications in the LRC’s portfolio, was developed in collaboration with the ITEST COP. The authors presented the COP with topics to consider and asked for input, and ITEST project PIs commented on drafts through an online symposia hosted by the LRC in partnership with the NSF, key stakeholders, and partners. Members of the

COP also added to the discussion by providing a rich array of project cases, research-based strategies, and program-related content to illustrate key points. The COP's active involvement in the symposia helped ensure the articles represent the perspectives of the ITEST community as well as policymakers, practitioners, and researchers in these fields. The symposia also proved to be timely and useful for the LRC and the COP—helping lay the groundwork for a major data collection effort (the recently-launched Management Information Systems [MIS]).

From its unique vantage point, the LRC has observed the pioneering efforts of ITEST projects as they transformed themselves into a robust COP whose work has only just begun. As the community expands, the knowledge sharing and synthesis of ideas also grow. The LRC has witnessed kernels of ideas begun in “working groups” become collaborative research projects and has shepherded the ability of emeritus PIs to mentor new PIs. From the powerful and concerted efforts of the COP, the LRC has also seen new research questions emerge from the intensive collaborations across projects with similar interests. And, the LRC works closely with the COP to anticipate future questions.

The COP's many contributions to this report symbolize its level of investment and central role in advancing the program's mission and goals. As Bredin and Hartry note in “The ITEST Community of Practice,” the burgeoning and vibrant COP is one of ITEST's greatest assets—and one of the greatest strides the program has taken toward sustaining innovative STEM education and workforce development. Again and again over the past seven years, the LRC has witnessed the power of convening the COP. Bringing the community together enables projects to face common concerns and explore how theory meets practice both in and out of school. The LRC's convenings have also prompted the COP to uncover and investigate many of the issues discussed in this report.

“Anticipatory Research” in the ITEST Community of Practice

The LRC studies patterns and trends within the ITEST COP through activities such as an annual summit, topical webcasts, online dialogs, individual technical assistance support, and small working groups. Remaining purposefully vigilant in identifying emerging patterns and trends has given the LRC staff an “anticipatory” mindset about the kinds of data that should be collected to describe the ITEST experience. The preparation of this report led the LRC to both reflect on existing challenges and explore the following questions that are emerging in the field as educators seek to ensure that students are equipped to thrive in a global “innovation economy.”

STEM Career Development

- What does it take to effectively interest and prepare students to participate in the STEM workforce of the future?
- What does it take to motivate youth to persist in STEM learning?
- How can we assess and predict inclination to participate in the STEM fields, and how can we measure and study the impact of various models to encourage that participation?
- How can we best support learners to make a successful transition to STEM careers—particularly those from underrepresented groups who can provide the diversity in thinking that will help our nation succeed in an innovation economy?
- What is the relationship of informal learning to STEM career development?
- What does the STEM career development pathway and model look like when formal and informal STEM learning experiences are fully integrated?

Engaging STEM Educators and Industry Professionals

- What are the most effective approaches for professional development needed to build and retain a robust cadre of STEM educators?
- How do we engage industry volunteers in ways to bring authentic STEM workplace knowledge and experiences into our classrooms?
- What impact do industry volunteers have on helping youth develop a sense of efficacy as scientists and engineers?

Preparing for the Innovation Economy

- What will ensure that the nation has the capacity it needs to guide and participate in transformative STEM advances?
- What does it take to develop the next generation of STEM innovators?

CyberLearning and Cyberworking

- How can the nation's burgeoning cyberinfrastructure be harnessed as a tool for STEM learning in classrooms and informal learning environments?
- What are the knowledge, skills, and dispositions that students need in order to participate productively in the changing STEM workforce and be innovators, particularly in STEM-related networked computing and information and communication technology (ICT) areas?
- How do students acquire this knowledge and these skills and dispositions?

The size of the ITEST Program and its reach into urban and rural communities and other under-served populations—as well as its potential for continuation—position it to make a significant contribution to STEM research and practice. The commitment of PIs to collaborate on emerging issues facing the field provides a unique opportunity for the ITEST COP to drill down into STEM education and workforce development issues and

generate data that can be mined to help answer these important questions in a timely way and within the constraints of limited resources. This capacity renders the ITEST Program a significant resource to the national STEM education and workforce development communities.

ITEST's Role in Building a Pipeline of STEM Innovators

In his September 21, 2009 address on innovation and sustainable growth, President Obama noted that, “a new generation of innovations depends on a new generation of innovators” (Obama, 2009). He also observed that at every point in the education pipeline, “. . . too many people—too many of our young talented people—are slipping through the cracks. It's not only heartbreaking for those students, it's a loss for our economy and our country.”

In its seventh year, ITEST is learning more about what it takes to shore up and strengthen the pipeline to prevent students slipping through. The program effectively engages students, teachers, and other educators in exciting, authentic, technology-based activities and learning environments. Programs like ITEST strive to connect workforce development needs and K–12 learning in and out of school. To understand that connection, we need to consider how the skills, knowledge, and attributes developed over time through formal and informal learning play a pivotal role in shaping students' career development and therefore, development of our workforce.

The ITEST program offers important opportunities to learn about students' experiences with STEM learning during these formative years:

- The ITEST experience—including more than 160 projects across 39 states—is helping young people and teachers in urban, suburban, and rural communities build the skills and knowledge needed to succeed in a technologically-rich society.

- ITEST impacts more than:
 - 189,800 K–12 students
 - 6,800 educators
 - 2,000 parents and caregivers
- ITEST focuses on populations traditionally underrepresented in STEM: African-American, Hispanic and Latino, American Indian, and female.

ITEST has become a mature program with an historical perspective. Exiting PIs are able to remain connected to the ITEST COP and can contribute information about their projects and effective strategies for engaging both youth and educators. The ITEST LRC recently implemented the MIS, which will leverage the vast information resource available within the COP. Additionally, the program has recently received funding to conduct research and small-scale studies, as well as to scale-up projects that have proven successful.

Participants in ITEST are involved at a level of intensity and duration that allows for some measurable progress to occur in knowledge acquisition and skill development. ITEST focuses on a wide range of STEM experiences that cover computer and environmental sciences, biotechnology, and engineering. ITEST participants are learning to use many of the same technology tools used by scientists and engineers. For these reasons, ITEST is well positioned to help answer some of the complex questions concerning what it takes to develop a pipeline of talent that meets our workforce needs in the 21st century.

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This project has been undertaken with much enthusiasm by those at the ITEST LRC. We are honored to help formal and informal educators share knowledge about “best practices” to engage underrepresented youth in STEM. Through our work with the 160+ funded ITEST projects, the LRC has cultivated a “community of practice” with a unique view of the strategies that work most effectively. We’d like to thank the ITEST projects for helping us create this community. Your passion and commitment to your work is an inspiration and *our* work would be impossible without you.

We would also like to thank our parent organization, Education Development Center, Inc. (EDC), for their support, leadership and vision. EDC has been on the forefront of education, health, technology, and workforce issues for over 50 years.

The National Science Foundation funds the ITEST Program and the ITEST LRC. The project has been so successful due in part to the leadership of many NSF Program Officers, who are too numerous to mention here. In particular, we would like to thank our current Program Officers—Julia Clark, Sylvia James, and Larry Suter—and our former Program Officer, Michael Haney. We value their support and our cooperative working relationship.

The Managing Editor would like to personally thank the PIs and other staff at the ITEST LRC. They have displayed an incredible amount of endurance throughout the process of creating this publication and continue to inspire with their knowledge, creativity, and ability to respond to tight deadlines! It is a pleasure to work with all of you.

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Suzanne Reynolds-Alpert
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ITEST and Workforce Development

Joyce Malyn-Smith

“A highly skilled workforce is seen as the key to economic growth and prosperity and the quest for economic growth and prosperity remains at the core of public policy.”

—Giddings & Barr-Telford, 2000

“But it’s not just that a world-class education is essential for workers to compete and win, it’s that an educated workforce is essential for America to compete and win. Without a workforce trained in math, science, and technology and the other skills of the 21st century, our companies will innovate less, our economy will grow less, and our nation will be less competitive.”

—Obama, 2008

Introduction

The United States faces an urgent need to build a pipeline of talent to fill positions soon to be vacated by retiring scientists, technicians, and engineers (Hira, 2007). A wave of recent reports has raised concern over impending shortages in America’s science and technology workforce (Business Roundtable, 2005; Committee on Prospering in the Global Economy of the 21st Century: An Agenda for American Science and Technology, 2007; Council on Competitiveness, 2008). These and growing pressures of global competitiveness and a slowing economy provoke us to ask questions about what we are learning to inform policy and practice in STEM (science, technology, engineering, and mathematics) education and workforce development, and to find new ways to tighten and speed the research/practice cycle.

The Innovative Technology Experiences for Students and Teachers (ITEST) Program offers a valuable resource to examine the most current practices in STEM education and workforce development, to validate existing questions, and to raise new questions to drive research. As the ITEST Program matures, data collection at the program and project levels can be organized and mined to answer questions in a timely and efficient manner.

In addition, ITEST stories provide insight into the minds and hearts of participants. These stories illuminate the intersection of formal and informal STEM learning, career development, and workforce development in the lives of today's youth. As we reflect on examples from the first five years of the ITEST Program, we see seeds of new knowledge around what it takes to develop interest in STEM careers, to acquire the skills and competencies needed to persist in STEM learning, and to prepare for a future in the STEM workforce.

Other articles in this series explore the important roles that high-quality informal learning experiences (see *Working in Afterschool* on page 32) and engaging underrepresented youths in STEM learning (see *Equity and Diversity* on page 22) play in creating a pipeline of STEM talent. This section, however, focuses specifically on four interrelated topics:

1. Skills and abilities required for success in the 21st century workforce and ITEST projects' cultivation of these essential skills in youth.
2. Strategies that ITEST projects use to support youth in acquiring the skills and abilities needed to participate in transformative discoveries in STEM.
3. Insights the ITEST Program, its principal investigators (PIs), and its projects can contribute concerning what youth know and are able to do with technology and their potential for STEM learning.
4. Reflections regarding the aspects of ITEST that might motivate youth—particularly those from groups traditionally underrepresented in STEM fields—to pursue STEM careers.

This article concludes by suggesting directions that ITEST might take to leverage the resources of the ITEST community to inform policy and practice in STEM education and workforce development.

How the ITEST Program is Helping Meet the Challenges of Learning and Working in the 21st Century

The 21st century has ushered in a new technological landscape that affects how people of all ages live, learn, and work. In classrooms and workplaces across the country, there is an increased focus on the skills needed to compete in a global knowledge economy. To retain our competitive edge, the United States needs to develop a workforce that is creative, innovative and able to use technology tools (Business Roundtable, 2005; Committee on Prospering in the Global Economy of the 21st Century & Committee on Science Engineering and Public Policy, 2007; Council on Competitiveness, 2008; Domestic Policy Council Office of Science and Technology Policy, 2006). Today's knowledge economy requires skills of collaboration, creative thinking, problem-solving, flexibility, and the ability to innovate (Partnership for 21st Century Skills, 2008), enhanced by “expert thinking and complex communication” (Levy & Murnane, 2005). According to Levy and Murnane, expert thinking refers to the ability to solve new problems by applying novel solutions, using information processing that cannot at this time be programmed and solved using computers; while complex communication requires the ability to interact with humans in complex tasks, such as persuading others toward a course of action.

These technological and economic changes call for a rethinking of education. In *Transforming Learning for the 21st Century*, Chris Dede and colleagues (2005) say that “The primary challenge for U.S. education is to transform children's learning processes in and out of school and to engage student interest in gaining 21st century skills and knowledge. Education must align curriculum and learning to a whole new economic model” (p. 3) for which powerful and proven (educational) models are lacking. STEM (science, technology, engineering, mathematics) literacy is also critical for “every citizen[,] in order to become a scientifically literate person able to function in a society where science has a major role and impact [on daily life]” (Huppert, Lomask, & Lazarowitz, 2002, p. 807).

The demand for creative use of technology tools in the learning process is driven by our deepened understanding of the technical skills and knowledge needed to be successful producers and consumers in this global knowledge economy, and the new ways of working that have emerged in a world where teams are geographically distributed and products/services are created and produced in virtual environments. Contributing to this demand is our increased awareness of the important role that computational sciences and computational tools play in our ability to innovate, which many believe is our “competitive edge” in the 21st century economy. Underpinning this demand is our increased understanding of the changing learning processes occurring when people use technology tools to learn, and recognition that science and technology literacy are essential to function well in life and work.

In response to these challenges the National Science Foundation (NSF) is focusing attention on formal and informal science learning and emphasizing the use of emerging cyberinfrastructure tools and resources by learners of all ages (National Science Foundation, 2008). The Innovative Technology Experiences for Students and Teachers (ITEST) program—formerly titled Information Technology Experiences for Students and Teachers—within the Division of Education and Human Resources at NSF is one such program. ITEST is designed to discover and disseminate best practices for developing the next generation of STEM talent. Now in its seventh year, ITEST “responds to current concerns and projections about the growing demand for professionals and information technology workers in the U.S. and seeks solutions to help ensure the breadth and depth of the STEM workforce” (National Science Foundation, 2009) by engaging students, teachers, and other educators in compelling, authentic, technology-based STEM activities and learning environments.

ITEST provides an opportunity for teachers to open their practices to new ways of learning for their students and themselves and to break down some of the traditional barriers to learning (e.g., connecting learning across formal and informal education, linking academic and technical environments). ITEST provides an opportunity for teachers and students to work

hand-in-hand with STEM professionals to carry out routine tasks and solve complex science, technology, engineering, and mathematics problems using sophisticated technology tools and processes. The ITEST effort leverages the talents of teachers and grows their ability to be successful educators by helping them form these new bridges.

What Skills and Abilities Are Needed for Success in the 21st Century Workforce?

The nature of the workplace has changed dramatically in response to rapid technological advances and the ubiquitous use of technology across all industry sectors. It has become increasingly important for educators—often isolated from business/industry—to understand the knowledge and skills effective professional, technical, and service workers must possess to live and work in a global economy and to create and innovate in technology-enriched STEM work environments.

Overshadowing these workforce development concerns are economic and human fears. What if the U.S. workforce is not prepared to meet the new demands of the 21st century? Could we lose our competitive edge and send rippling effects throughout our economy? Our STEM visionaries—inventors and scientists who combine superior skills and imagination—can invent solutions to persistent and threatening challenges to our well-being. They can invent green technologies and create new options to address United Nations Millennium Goals, for example. It is in the nation’s best interest that we have a continual pipeline of such talent.

Since the early 1990s, employers in the international community have agreed upon the essential skills needed for success at work. These skills, clearly identified and integrated into the national School to Work Movement, are found in *Workplace Basics: The Essential Skills Employers Want, Training Manual* (Carnevale, Gainer, & Meltzer, 1990) and *What Work Requires of Schools: A SCANS Report for America 2000* (Secretary’s Commission on Achieving Necessary Skills—SCANS, 1991). *Workplace Basics* and *What Work Requires of Schools* both describe a “Foundation” (SCANS, 1991)

of competencies and characteristics needed by a “new kind of American worker” (Carnevale et al., 1990). Key competencies include basic literacy, communication and computational skills, and mastery of “learning how to learn.” Personal characteristics include the ability to work well in teams, adapt, problem solve, and engage in critical thinking.

In addition to this “Foundation,” the emergence of the 21st century knowledge economy and global competition brought the need for a more creative and adaptable workforce able to effectively use technology tools (Business Roundtable, 2005; Committee on Prospering in the Global Economy of the 21st Century, 2007; Council on Competitiveness, 2008; Domestic Policy Council Office of Science and Technology Policy, 2006). “Expert thinking and complex communication” (Levy & Murnane, 2005) were identified as core skills needed for creative work and call for a rethinking of education for learning and working in the 21st century.

The Partnership for 21st Century Skills (2008) framework addresses these needs by advocating that all who prepare youth for their futures (e.g., schools, out-of-school programs, workforce developers) expand their focus to foster “21st century student outcomes” in five strategic areas:

- Core Subjects—World Languages, Arts, Economics, Science, Geography, History, and Government/Civics
- 21st Century Themes—Global Awareness; Financial, Economic, Business, and Entrepreneurial Literacy; Civic Literacy; and Health Literacy
- Learning and Innovation Skills—Creativity/Innovation, Critical Thinking/Problem Solving, and Communication/Collaboration
- Information, Media, and Technology Skills—Information Literacy, Media literacy, Information and Communications Technology (ICT) Literacy
- Life and Career Skills—Flexibility/Adaptability, Initiative/Self-Direction, Social and Cross-Cultural Skills, Productivity/Accountability, and Leadership/Responsibility

“Learning of 21st Century skills can bring academic education together with career and technical education. Central to innovative technologies is ‘design thinking.’ The learning of essential skills should be an explicit emphasis in all ITEST projects—with the inclusion of quantitative reasoning and design thinking (of which computational thinking is a subset). More emphasis should be placed on problem based learning that brings the workplace into the classroom. A question that could be studied is: Can problem-based learning engage students in deeper study of STEM resulting in increased learning of the disciplinary concepts as well as essential skills?”

—Dr. Gerhard Salinger, Program Officer Advanced Technological Education and ITEST, National Science Foundation (Salinger, June, 2009)

In *Transforming Learning for the 21st Century*, Chris Dede and colleagues (2005) assert that our nation must also focus on what we know about how people learn, especially the new generation of technology natives, as these early adopters are our meters of the future: “Internet-based learning styles ascribed to ‘millennial’ students born after 1982 are increasingly true for many people across a wide range of ages, driven by the tools and media they use every day” (Dede, Korte, Nelson, Valdez, & Ward, 2005, p. 4).

At NSF’s August 24, 2009 Expert Panel Discussion on *Preparing the Next Generation of STEM Innovators*, Dr. Cora Marret, Acting Deputy Director of NSF, defined innovation as the “process that generates new ideas and converts them into novel, useful and viable products, services and practices” (Marret, 2009, p. 3). As a panelist, Dr. Michael Cima of MIT’s School of Engineering/InnovaTeams proposed attributes of “innovators” to include curiosity, empathy, and leadership and defined innovative groups as small groups, with a clear image of excellence, an ability to reinvent their mission, diversity of experience/perspective, and an absence of fear of failure (Cima, 2009, pp. 2–4). As we reflect on the examples and activities described in this article, we see many of these individual and group characteristics of innovation mirrored in the ITEST experience. ITEST may have much to contribute to our understanding of what it takes to nurture the talents of young innovators and develop a culture of innovation in our schools and communities.

ITEST Projects Cultivate New Essential Skills Needed for Workplace Success

ITEST youth develop many of these essential skills needed for workplace success and gain firsthand experience in solving problems that foster creativity and innovation. In most ITEST projects, students work in teams along with scientists, technicians, and engineers, using real tools to solve authentic workplace problems.

For example, TechMATH: Real World Math, Technology, and Business Connections (ITEST Cohort 4) creates teams that include a math or science teacher, a student, and a local business partner. Teachers and students visit the partner's business and work with staff to solve a problem facing that business. Each team develops a teaching module that fits into existing curriculum, connects to academic content, and relates to the business partner's problem. Teachers then integrate the modules into the classroom to help students learn about the role of math and science knowledge and skills in the STEM workplace and to understand better what it means to work in STEM careers.

In the Information Technology (IT) Community Support Project (ITEST Cohort 4), 352 middle and high school students from Hartford, Connecticut, are experiencing what it is like to run a business. Through a partnership with the University of Hartford and its Career Counseling Center, the students receive career counseling and complete a business skills workshop that enables them to operate "Our IT," a student-run business that provides IT training and support to the local community. Students become "Explorers" of IT careers through studies of computer architecture, network systems, Web design, and communications. As "Specialists," students learn software development, advanced communications, and business skills, and as "Entrepreneurs" they provide computer skills training for the community. Students receive training in workforce skills, mentoring, and A+ certification and participate in paid internships. They gain IT skills in computer engineering and Web applications, produce a DVD on IT careers, create a project website, and refurbish computers for donation.

Young women and youth of color traditionally underrepresented in STEM fields are developing workplace skills while taking on the role of scientists and engineers in Engineering Design and Practice: Using our Human Capital for an Equitable Future (ITEST Cohort 5). This multi-year design and problem-solving experience includes summer internships/externships and university research in the science center and industrial settings where youth develop socially responsible solutions for challenging, real-world problems. In cognitive apprenticeships with diverse mentors, students practice workplace skills such as leadership, teamwork, time management, creativity, and reporting. As scientists, they use technological tools to gather and analyze complex data sets. Students simulate desert tortoise behaviors, research and develop designs to mitigate the urban heat island effect, build small-scale renewable energy resources, design autonomous rovers capable of navigating Mars-like terrain, and develop a model habitat for humans to live on Mars. The project measures participant content knowledge of, attitudes toward, and interest in STEM subjects, workplace skills, and intentions to pursue IT/STEM educational and career pathways to understand participant reactions, learning, transfer, and results.

These few examples illustrate how ITEST provides a rich testing ground to explore ways to move us, as a nation, toward developing a pipeline of STEM talent with the essential skills needed for workplace success. In addition, as we detail below, ITEST projects offer an array of potentially effective strategies to prepare today's technologically able youth to participate in transformative discoveries in STEM.

What Strategies Do ITEST Projects Use to Support Youth in Acquiring the Skills and Abilities Needed to Participate in Transformative Discoveries in STEM?

A Profile of Today's Youth and How They Learn

The students served by ITEST projects—like their peers nationwide and around the globe—use computers, cell phones, video games, and technology tools in greater numbers each year to live and learn in the digital age. By 2005, teens in America spent more than 6.5 hours per day engaged with media; 28 percent used computers and 22 percent played video games for more than one hour per day (Roberts, Foehr, & Rideout, 2005). That same year, The Pew Charitable Trusts reported that 21 million teenagers (87 percent) used the Internet, of whom 51 percent went online daily (Lenhart, Madden, & Hitlin, 2005). By December 2007, Pew reported that 97 percent of teens use the Internet and calls 28 percent (mostly older girls) “super communicators.”

Although 81 percent of young Internet users play games online, youth also use the Internet for other purposes: 75 percent get news online, 43 percent make purchases online, and 31 percent use the Internet to get health information. As youth have developed greater expertise with technology tools, they are shifting from being simple consumers or “users” of technology to content “producers,” as 64 percent of today’s online teens engage in content creation (Lenhart, Madden, Macgill, & Smith, 2007). This is a subtle but important shift that reflects youth’s growing mastery over technology and their desire and ability to use technology to create and innovate.

“Technology should be used comprehensively and purposefully. The use of technology in the classroom not only prepares children to live and work in a high-tech society but also helps them understand mathematical concepts in powerful ways. In the innovative initiatives and programs provided for students, computers must not be the only tool used. Students need to be provided with technological tools that will enable them to communicate, learn, collaborate, create, and to think and solve problems. By providing students many means of learning using technology can transform learning experiences in many productive ways.”

—Dr. Julia Clark, Lead Program Officer, ITEST, National Science Foundation (Clark, June, 2009)

Research on brain plasticity and learning tells us that experience shapes learning and that learners who have developed expertise think and learn differently from novices (Bransford, Brown, & Cocking, 2000; Carey, 2006). In a study of identity characteristics, Yoon found that youth who were “Power Users of Information and Communications Technologies” demonstrated learning characteristics and thinking dispositions that reflect this expertise. Their metacognition levels match what some education-focused researchers consider to be centrally important to 21st century society (Yoon, 2007). Yoon details their identity characteristics, learning characteristics, thinking dispositions, goal orientation, and commitments. She describes them as being self-teachers and problem solvers, who learn mainly through experimentation. They possess strategic thinking skills, are goal-oriented, and committed to seeking out new learning opportunities.

Ryberg and Dirckinck-Holmfeld (2008) propose a metaphor of “patch-working” to describe how “Power Users of ICT” engage in knowledge creation as they plan, stitch together, create, reweave, and connect “patches and pieces” of existing knowledge to create new patchworks, or new knowledge. The potential impact on education and economic development of these highly developed cyberlearners is an issue of interest to the international development community and countries seeking a position

of strength in the global knowledge economy (Dossal, 2003; Malyn-Smith, 2004). Whether they use technology tools or not, youth today are able to learn fundamental computer science concepts that influence computational thinking and K–12 teachers are able to integrate those computer concepts successfully into the K–12 curriculum (Bell, Witten, & Fellows, 2002; Blum & Cortina, 2007; Tucker et al., 2006).

ITEST Projects Tap Youths’ Zeal for Technology to Support Their STEM Cyberlearning, Acquisition of 21st Century Workforce Skills, and STEM Career Planning

By focusing on the use of technology tools in the service of STEM, ITEST projects are providing opportunities to explore the role of cyberlearning (National Science Foundation, 2008) in career and workforce development for the global knowledge economy. The following two examples of ITEST projects share a common interest in learning more about how today’s youth think and learn. In various ways, each project is exploring the emerging concept of “technological thinking” or “computational thinking” and problem-solving in technology environments. Together, they are generating data on how the ready adoption of new technology—and new ways of thinking and learning—of youth who are essentially “digital natives” is shaping the development of our next generation of scientists, technicians, technologists, and engineers. These projects serve as exemplars of how to effectively help youth visualize themselves in STEM careers while inspiring others to help students persist on this educational pathway. They also provide valuable insights to educators developing curricula that shape the learning trajectory of today’s youth. These stories help us understand the learning potential of youth empowered with technology and their ability at early ages to develop sophisticated technology skills and understand complex technological, scientific, and mathematical concepts.

The Girl Game Company (ITEST Cohort 4) is designed to support young women in becoming producers—not just users—of technology. Eighty Latina, middle-school girls from the Central Coast of California are

building and publishing Web-based digital games that imagine life in outer space based in astrobiology content. Each girl spends 120 hours per year for two years building and publishing the games. The project utilizes Numedeon, Inc.’s online virtual world “Whyville?” combined with the SETI Institute’s astrobiology curriculum. Process strands support and evaluate IT/science activity, group cohesion, learning by design with project-based IT, linking science to IT, and career and identity exploration. Strategies to meet each girl’s social needs include pair programming, peer mentoring, family activities, and adult female IT role models. A study of the project found “significant increases from pre- to post-test in participants’ computer skills, confidence in working with computers, and independent problem-solving skills” (Denner, 2007). The study also noted “significant decreases in girls’ endorsement of gender stereotypes (for example, believing that boys do better than girls on computers.)

“In the Girl Game Company, we are exploring whether computer game design and programming has implications for the development of the kinds of thinking that will prepare youth to be innovators in the future IT workforce. We are also studying what ‘thinking like a computer scientist’ looks like in middle school.

To this end, we have developed and are testing strategies for measuring the development of computational thinking by coding student games ...We developed the coding system for the games based on college-level definitions of IT fluency. In particular, five aspects of algorithmic thinking or modeling and abstraction were identified as relevant: (1) events; (2) methods; (3) variables or parameters; (4) alternation (conditional execution); and (5) parallelism. Games are being coded for the frequency with which each of these constructs appear, and we will examine whether and how the use of these constructs changes over time (from the students’ first to their final game).”

—Dr. Jill Denner, PI, Girls Creating Games, ITEST Cohort 4 (Denner, 2007)

In the SUCCEED Apprenticeship Program (ITEST Cohort 3), more than 100 Grade 8–10 students in the communities of Durham and Orange Counties in North Carolina are learning computer modeling and simulation and participating in apprenticeships on projects such as the National Digital Science Library (meta tagging and Web design), Digital Durham (postcard database), SUCCEED (website design/Web applications), and Sigma Xi (Web support). Project SUCCEED offers formal workshops and classes in the theory and practice of computational science—which the project defines as “that aspect of any science in which computation plays an essential role”—both as stand-alone classes and as a prelude to full research apprenticeships for some students. A blend of lecture and directed laboratory exercises enables students to learn in a hands-on environment and supports them in developing the capacity to work independently. Working alongside accomplished mathematicians, scientists, and educators, SUCCEED participants learn to make the appropriate match of application, algorithm, and architecture which is at the heart of computational science. At the same time, and equally important, they “learn how to learn”—experiencing the excitement of discovery, the power of inquiry, and the joy of learning.

“We have the challenge and opportunity to help students see that computing really matters. Computational thinking matters because quantitative reasoning touches all aspects of a liberal education. Multi-scale modeling is the intellectual ‘heart and soul’ of 21st century mathematics and the physical and social sciences and therefore is one of the essential skills of the 21st century workforce. Computational thinking matters because we can demonstrate the power of interactive computing to help all students and teachers reach a deeper understanding and application of data in every content area. Computational thinking matters because computational tools integrated with curriculum become both the content of STEM education and a most effective tool for learning.”

—Dr. Bob Panoff, PI, SUCCEED Apprenticeship Program, Shodor Institute, ITEST Cohort 3
(B. Panoff, personal communication, September, 2008)

Across the country, these and other ITEST projects are pioneering strategies that nurture the talents of cyberlearners to be “producers”—making meaning as they create content. They are expanding our knowledge of how to prepare youth to engage in transformative STEM discovery. In doing so, the ITEST projects are also contributing to a reconceptualization of youth IT fluency by generating data on the specific technological skills and STEM capacity of a diverse group of cyberlearners—ITEST’s 189,000-plus youth participants who stand poised at the entry of the STEM pipeline.

ITEST Projects Promote Participants’ Use of Technology to Perform Cutting-Edge Procedures

In New Mexico Adventure in Modeling: Integrating IT into the Curriculum through Computer Modeling Approaches (ITEST Cohort 1), teachers at the secondary level integrated IT concepts and computer modeling, especially complex adaptive systems, into their curricula. To do so, they used StarLogo simulation software, participatory simulations using handheld computers, and related computer technologies. Students analyzed, explored, designed, and built models of complex adaptive systems using StarLogo and the Adventures in Modeling curriculum. Students learned: (1) design and presentation of information as they developed computer simulations that conveyed specific principles; (2) system design and analysis as they designed and conducted experiments using simulated systems; (3) data analysis tools and techniques as they collected data from their experiments and analyzed it using spreadsheets, graphing tools, and statistics; and (4) computer modeling and simulation techniques that have broad applicability across many scientific and technological domains.

Bioinformatics: The Rutgers Initiative in Teacher Enhancement (BRITE) (ITEST Cohort 2) used the computational tools of molecular biology, structural biology, and bioinformatics with high school students, who addressed a series of scientific challenges. Students in BRITE learned how to extract, identify, and analyze DNA sequences from worm speci-

mens. Using Web-based tools and other instruments, students were able to access bioinformatics resources that deepened their understanding of biological processes. These activities provided students the opportunity to use instruments and tools that are “used by professional scientists in analyzing DNA sequences,” providing direct exposure to and understanding of this field.

“The Global Challenge Award (ITEST Cohort 4) has documented the acquisition of knowledge and skills related to forming and working in global teams using technology to solve complex problems. Specific skills measured include pre and post self-reported levels of learning opportunities and quality of experiences (as well as attitudes) in items drawn from a variety of national and international sources.

Quantitative pre-post measures have documented the program’s impact on both general academic performance in mathematics and science as well as specific STEM content knowledge entailed in GCA’s online learning explorations. Affective and descriptive measures include survey items adapted from NELS, PISA, AWE, ISTE, and the Partnership for 21st Century Schools. The findings, in addition to gains in STEM knowledge, include increased interest in STEM careers focused on environmental studies, international business, and entrepreneurship. An increased awareness of global climate issues is another important outcome, with many students expressing their desire to continue working with the project on the problem of climate change in some role, either as second and third year participants or as mentors to younger students.”

—Dr. David Gibson, PI, Global Challenge Award ITEST Project (Gibson, June, 2009)

What Insights Can the ITEST Program and Its Projects Contribute Concerning What Youth Know and Are Able to Do with Technology, and Their Potential for STEM Learning?

Nurturing interest and persistence in STEM education while effectively scaffolding learning to ensure that workplace competence is accessible and achieved is the goal of our STEM education system. Building a bridge between what youth know and are able to do in STEM and the skills/knowledge needed for workforce success is key to developing a robust pipeline of STEM talent. ITEST’s Youth and Technology Working Group took the first step towards building this bridge by asking and describing what ITEST youth know and what they do with technology and aligning these to current models of ICT Fluency.

During the course of the Youth and Technology Research Working Group’s analysis of existing models, it rapidly became clear that while the models provided valuable frameworks for defining ICT literacy, most did not reflect the depth of conceptual understanding around technology systems and the breadth of technology skills learned and practiced by today’s cyberlearners. The “FITness” IT Fluency model (National Research Council, 1999) comes closest to representing the depth of IT knowledge by identifying Intellectual Capabilities and Fundamental Concepts along with Contemporary Skills as three components of IT Fluency. The ITEST experience, however, helps us understand better how prior models do not reflect the experience of today’s youth with technology tools. ITEST PIs identified four primary applications used within the ITEST community. The model below illustrates the “fit” between the essential components of the “FITness” IT Fluency model, the five ITEST applications found across ITEST projects, and the five ITEST domains that describe the experience of youth in the ITEST community during its first five years. These formed the basis for the working group’s study.

During the spring and summer of 2008, the Youth and Technology Research Working Group administered a survey designed for the staff and educators of current ITEST projects to report on what their youth participants know about and can do with technology. The survey asked about the use of tools and technologies, and youth's mastery of them, in five areas: Computer Programming; Communication/Collaboration; Visualization; Computing and Analyzing Data; and Computer-Driven Equipment/Design and/or Building of Physical Objects or Environments. The following preliminary results are summarized from the 46 respondents who completed the survey. These respondents represent 36 projects or 50 percent of ITEST projects funded in Cohorts 3, 4, and 5.

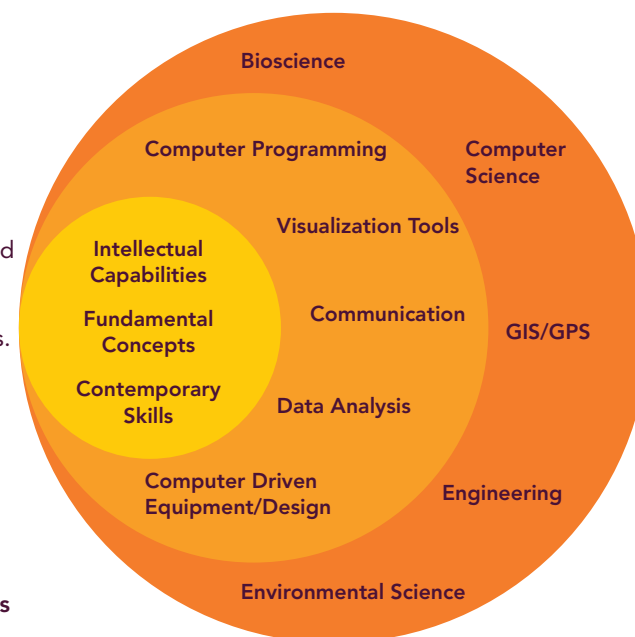
The results reported by project staff shed light on the range of technology tools that are used across the ITEST Program. The results also show that youth's mastery of these technology tools are more likely to be on the high end of the scale. That is, the occurrences of youth using technology tools independently and/or teaching them to others outweighs occurrences of those using tools with help or those who don't know how to use them at all. This is particularly true for youth: programming with Squeak, Stagecast, and Object Oriented Design; using communication tools such as e-mail and instant messenger; using visualization tools like digital still and video cameras, Garmin eTrex GPS, and Google Maps; and those using Microsoft Excel for computing and analyzing data. The survey results also reveal that youth in these projects are using various technology tools to perform cutting-edge procedures—from retrieving or uploading data or information to more sophisticated activities such as using an online tool to analyze DNA sequences, building dynamic webpages, and programming interactive games, software, or hardware.

These results provide an initial view of which tools and technologies are being used in ITEST projects, how they may be used, and the varying skill levels in different areas. Because the mastery levels are reported by project staff about youth, it is difficult to determine the exact range in youth skills with these technology tools. However, these findings reveal that ITEST projects are exposing youth participants to innovative, technology-advanced learning experiences.

FITness Components
Represents IT Fluency as integration of three kinds of knowledge and skills: thinking skills, computer concepts, and skills using IT tools.

ITEST Applications
ITEST projects use technology in these five ways.

ITEST Project Domains
ITEST participants apply their ICT Fluency to routine tasks and solving problems in these domains.



Singularly and taken as a whole, the stories emerging from the ITEST projects' experiences raise awareness of the growing technology capacity of today's youth—and ability to engage deeply in STEM learning—when given the opportunity, tools, and support needed to experiment and excel. ITEST youth are engaged in deep science learning in which they are developing sophisticated technology skills. These examples help us see the potential for synergy between science and technology learning and the potential of the ITEST community—with its broad reach across the U.S. into urban, rural, and suburban communities and into formal and informal learning environments—to gather data to learn more about the capabilities of today's youth. At the same time, the ITEST projects also have the potential to contribute to our nation's understanding of the factors that influence youth's selection of STEM careers and the kinds of instruction or experiences that motivate them to do so.

Reflections and Next Steps

In its seventh year, ITEST is learning more about what it takes to prepare the next generation of STEM talent. The program effectively engages students, teachers, and other educators in exciting, authentic, technology-based activities and learning environments. Programs like ITEST strengthen the connections between K–12 learning in both formal and informal environments, teacher professional development, and changing STEM workforce needs. ITEST has become a mature program with the advantage of being continuously informed by current practice and able to draw upon institutional knowledge through the ongoing participation of former ITEST PIs who are members of the ITEST Emeritus alumni group. Emeritus PIs mentor new ITEST PIs and continue to contribute information about their former ITEST projects and effective strategies for engaging both youth and teachers. This current and historical perspective housed in the ITEST community of practice offers valuable short- and long-term views that can inform policy and practice on many of the issues affecting STEM education and workforce development.

As the LRC expands its project information collection to include common data elements across the entire ITEST program, its project information database will evolve into a rich repository that accurately describes STEM education and workforce development experiences of students and teachers. This database will become a valuable resource to researchers, policy-makers, and practitioners who seek answers to questions that smaller, short-term programs are not equipped to handle. ITEST is an extraordinary national resource that describes and examines STEM education, career, and workforce development issues and contributes to our understanding of what works.

We live in a time of fast-paced change. What was recently a booming technology-based economy has faltered. We face serious economic challenges of an aging workforce and recession. Concurrently, the development of new technologies has opened up opportunities for breakthrough thinking and innovation, not only in STEM fields such as biomedicine and engineering but in all industry sectors including business, agriculture, and energy.

Young people empowered with technology are changing the ways our society lives, learns, and works. With access to technology tools, information on any topic at their fingertips, and the ability to tap into social networks of expert scientists and engineers, today's self-directed learners possess incredible potential for creativity and innovation. Today's youth are tomorrow's innovators—and they will be called upon to generate new ideas and synthesize information in novel ways. Given the powerful attributes of the ITEST Program—the large numbers of youth participants from across the country, and the supportive, active, and dedicated community of educators and scientists—the ITEST LRC is poised to document the ITEST experience by gathering data to answer these important questions about what it takes to build a robust, reliable pipeline of STEM talent:

- What does the STEM career development pathway look like for majority and underrepresented—and other sub-groups of learners—when formal and informal STEM learning experiences are integrated and scaffolded?

- What does it take to motivate youth to participate in and persist in both STEM learning and preparation for STEM careers?
- How do we recognize and cultivate the unique talents of digital natives and other highly developed cyberlearners? What are the best means to motivate them to apply these talents to making transformative discoveries in STEM?
- How do we strengthen the capacity of scientists, engineers, and other industry volunteers to help youth develop STEM efficacy and persistence in STEM learning?
- What does it take to help youth develop the knowledge, skills, and dispositions needed to innovate, discover, and participate productively in the changing STEM workforce?
- How can the nation's burgeoning cyberinfrastructure be harnessed as a tool for STEM learning and career preparation?

By gathering further data and leveraging the power of each ITEST project to contribute to what ITEST is learning, we will realize the full potential of the ITEST Program. We will also contribute to a skilled STEM workforce that is ready to create, succeed, innovate, and transform the world around them.

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Equity and Diversity

Sarita Pillai

What Is the Current State of the STEM Education and Workforce Pipeline and What Is the Importance of Diversifying It?

The global, rapid technological advances taking place call upon the best minds in the science, technology, engineering, and mathematics (STEM) fields to work together in complex and significant ways. This, in turn, requires that people with diverse ways of working, thinking, and learning engage in challenging and fulfilling work in STEM areas (Committee on Equal Opportunities in Science and Engineering—CEOSE, 2004). Our nation, however, faces a number of challenges to remaining competitive in STEM industries—these include changing demographics and shortages of workers with the diverse skills and expertise necessary to produce the best advances in science and technology.

The continuing global technological leadership of the United States, therefore, depends on the development of the scientific talent of all its citizens. The nation must educate engineers and scientists who are efficient users and innovative producers of the emerging cyberinfrastructure. These STEM professionals must come from diverse backgrounds and be generative and creative, able to understand business issues, fluent in software use, efficient in networked collaborative design, comfortable with foreign languages and working in culturally diverse teams, and able to manage global projects where teams are geographically dispersed.

“The whole issue of attracting, developing and retaining the very best is really something that is mission critical for [industry]. We need ... to have the diversity of thought to be able to generate new ideas, promote better decision making ... to create a workforce that mirrors the world we’re a part of.”

—Carroll McGillin, National Initiatives Manager for the Cisco Networking Academy Program, Cisco Systems (ITEST LRC, 2006)

Tomorrow's workforce will be composed of individuals whose informal learning, formal education experiences, and personal life choices lead them onto specific career paths. The determining factor in whether they join the STEM and IT workforce may be how effectively those experiences and choices build authentic, marketable IT skills and sustain their interest in STEM careers. Unfortunately, just as the need to strengthen and diversify the IT workforce intensifies, our nation is experiencing a STEM "skills gap" that is growing wider. Women, minorities, and persons with disabilities continue to be largely underrepresented in STEM education and careers. Not enough young people take the science and mathematics courses that will prepare them for STEM careers, and, of those who do complete the requisite coursework, too few enter STEM professions upon graduation (National Center for Education Statistics—NCES, 2003; National Research Council—NRC, 2002). The formal and informal educators with whom these young people interact play a crucial role in their decisions to pursue STEM careers, and in doing so help determine the strength and diversity of the IT workforce.

"We're now talking about diversity in the context of workforce competitiveness. The underrepresented groups (women, African Americans, Hispanic Americans, older workers) in the high-tech industry constitute untapped talent ... We need to have CEOs and leaders who embrace diversity in practice; and identify best practices. And we need to ask ourselves, 'How do we create greater synergies between what employers are doing and what education, government, and community organizations are doing?'"

—Marjorie Bynum, formerly Vice President of the Information Technology Association of America (ITAA) (ITEST LRC, 2006)

How Are ITEST Projects Demonstrating Ways to Effectively Engage Youth, Particularly Those From Populations Underrepresented in STEM, and Foster Their Persistence in STEM Fields?

Congress funded NSF's ITEST Program in direct response to the concern about the shortage of IT workers in the U.S. (NSF, 2005). Under the auspices of the program, more than 160 ITEST projects in 39 states are pioneering new ways to involve diverse populations of youth and educators in intensive IT and science learning—and working with more than 189,000 students in Grades K–12, 6,800 educators, and 2,000 parents, in the process. These projects' STEM investigations range from creating electronic adaptive devices to community mapping with GIS tools. Without question, the projects offer unique learning environments for exploring critical dimensions that contribute to success in developing the future STEM pipeline. Yet, how much do we really know about what draws youths to STEM careers? And, what can ITEST help us learn about how to effectively engage today's youth, especially those from underrepresented communities, in STEM learning?

A study published in the journal *Science* indicates that student interest is an important predictor of later pursuit of scientific college majors (Tai, 2006). Retrospective studies have found that professionals and college students majoring in the sciences trace their interest in the field back to early positive experiences with science (Dorsen, Carlson, & Goodyear, 2006; Roe, 1952, as cited in Joyce & Farenga, 1999). Furthermore, students majoring in the sciences describe participating in informal science activities throughout middle and high school (Rennie, 2005; Tisdal, 2005). Some informal science education (ISE) programs have produced heightened understanding of how ISE can increase youth interest in STEM content and careers, especially at the middle and high school levels (Cavallo, Papert, & Stager, 2004; Creamer, Burger, & Meszaros, 2004; Fadigan & Hammrich, 2004). Overall, the literature has identified six key factors that connect informal STEM experiences to the choice to pursue future STEM

work: (1) expressed interest in pursuing a STEM career; (2) academic preparation and achievement; (3) identification with STEM careers; (4) self-efficacy; (5) external environmental factors that are barriers or supports; and (6) motivation, interest, and enjoyment (Dorsen et al., 2006). ITEST projects are ideally situated to address these factors and to foster the journeys of diverse populations of young people toward STEM careers. Through intensive recruitment strategies and hands-on projects that let students and teachers take the reins of their learning experience, ITEST principal investigators (PIs) and staff are reaching and engaging those traditionally underrepresented in the STEM disciplines. For example, The Paleo Exploration Project at the University of Montana-Missoula (ITEST Cohort 4) is training 60 middle school math and science teachers from rural, northeastern Montana—an area that includes three of the state’s seven Native American reservations—to involve their students in paleontology and geospatial analysis. These ITEST participants are learning about Montana’s geologic history and fossil record and mastering the use of sophisticated geospatial technologies in paleontological research. In another example, Eyes in the Sky (ITEST Cohort 1) focused its recruiting efforts on schools that serve large percentages of students of color. Although the boys in the group were initially more enthusiastic than the girls about using the global positioning system (GPS) units outdoors, Dr. Carla McAuliffe, co-PI, notes that staff and teachers “coached all the students through the course so that everyone gained new skills” and had success with geospatial information technologies (ITEST LRC, 2004). As these examples illustrate, ITEST projects possess several common characteristics that contribute to their success.

Inquiry-Based and Experiential Nature

A hallmark of ITEST projects is their inquiry-based and experiential nature. Youth need experiential, contextual STEM experiences that connect STEM subject matter to the real world. ITEST projects integrate formal and informal learning strategies in ways that reinforce the connection between discipline-specific and project-based learning. In addition, scientific inquiry is linked to all aspects of programming in which students

and teachers participate. (Read more in the article on Afterschool, page 32) Similarly, in teacher-focused projects, educators take part in active learning and engage in the same inquiry processes that they will later implement with students in their classrooms.

Contextualized and Culturally Relevant Content

ITEST projects strive to be highly contextualized and culturally relevant. ITEST activities are often rooted in local communities and center around specific cultural, local and regional issues of importance. “The cultural aspect of our program is very important,” says Dan Calvert, PI of Salmon Camp (ITEST Cohort 1), which partners with tribal elders and Native American scientists. “We find that as our participants are engaged in more culturally relevant activities, they get more excited. We’re trying to align Western science with traditional Native American knowledge.” He notes, “In many areas of natural resource management, these two are coming together. And, for some students, this is the first opportunity they have had to learn about their culture” (ITEST LRC, 2006).

Career-Focus

Projects are career-focused and expose youth to STEM career possibilities in a uniquely hands-on way. In ITEST projects across the country, youth are not merely learning about scientists or meeting them, they are “being” scientists, being engineers—making and sharing important scientific discoveries, working with public, national and international datasets, and interacting with STEM professionals from around the globe. In the Global Challenge Award ITEST Program (Cohort 4), diverse teams of high school students work together to create an innovative solution to address global climate change, while also exploring their solution’s global business potential. (Read more about this project in the Workforce article on page 8.) Similarly, the SPIRIT project at Purdue University (ITEST Cohort 3) is encouraging young women to pursue computer-related careers in order to foster a more gender-balanced IT workplace.

Community Focus

ITEST projects are emphatically community-focused and represent a coalescence of stakeholders across the education/workforce continuum, from formal and informal practitioners and their institutions, to families, communities, and businesses. This network of support is key to the success of the projects, which set ambitious goals for participating youth and educators. In the case of BITS (Building IT Skills among Inner City Youth—ITEST Cohort 2), a project based in Philadelphia, about half of the participating students failed their previous year of school or were making up credits in summer school. According to PI Michele Masucci, “Our focus is working with at-risk youth. We work with students we think have potential to go to college but who just don’t see it in their own futures.” Youth participants are involved in building a community GIS, and project staff cultivate relationships with community organizations as part of this work. Masucci describes their intensive mentoring program through Harrison Campus Compact (Temple University students), an important dimension: “The idea is to partner our participants with folks who are four, five, six years down the road from where they are. The students get a lot of one-on-one attention from the mentors, many of whom are from similar backgrounds” (ITEST LRC, 2006).

Who Are ITEST Participants and What Impact Is Their Participation in ITEST Programs Nationwide Having on Them, Their Peers, and Their Communities?

Widely dispersed in rural, urban, and suburban locations, youth participants are immersed in compelling, hands-on activities that seek to increase participants’ feelings of self-efficacy around IT, while allowing them to visualize their future selves doing STEM work. In addition, ITEST projects give young people skills they can apply in the classroom, promoting academic achievement.

ITEST’s teacher participants experience a lab environment that provides them with rigorous training in deep science content, as well as tools and strategies for implementing STEM investigations in their own classrooms. The summer practicum, a distinctive feature of the ITEST Program, requires teachers to work together with students for part of their professional development. This approach makes for an inclusive, collaborative learning experience that expands knowledge and enhances pedagogy as it builds a community of practice (COP) for participants (see *ITEST Teacher Professional Development—Distinctive Implementation of Best Practices* on page 41 and *The ITEST Community of Practice: Lessons and Implications* on page 54).

“How do you inspire kids to think of technology differently, to make it their own and use it as a tool? We’ve learned to give the kids external motivation: have a client or an audience that they’re serving with their work. Teens want an audience; they want their work to be real... finding ways for them to use the technology to give back to the museum and the community they live in has been really critical” (ITEST LRC, 2006).

—Kristen Murray, Co-PI, MyBEST (ITEST Cohort 1)

In Their Own Words: Student Participants in the ITEST Program are Impacted in a Variety of Ways

The following section illustrates the impact of the program on teacher and student participants. Across all cohorts of ITEST projects, participants are articulating how the program is enhancing STEM-related skills and thinking.

Students are Mentored and Exposed to Diverse Professional Mentors

In addition to offering youth valuable insights into the STEM interests of their peers and the professional lives of STEM professionals, mentoring also helps combat the negative stereotypes that often dissuade youth from pursuing STEM fields (the so-called “geek” factor).

“They had guest speakers, including a UC Santa Cruz scientist who’s working on the Human Genome project: a woman and an American Indian. I want her to come in to meet my students. Another grad student who works [with the program] . . . is a Hispanic male. I want my students to see that a variety of people can become scientists” (ITEST LRC, IdeaBrief, 2005).

—Linda Perkins, Teacher Participant, Marine Biotech (ITEST Cohort 3)

Students Are Encouraged to Think, Act Like, and Be Scientists

ITEST projects are integrating STEM career information into programs and activities in ways that allow young people and their educators to perform real scientific tasks and engage with each other as budding STEM professionals. The strategies that projects are using also promote positive perceptions of STEM fields and workplaces for those currently underrepresented in those fields.

“I’ve had the most unlikely students get engaged [in GIS] . . . The students can take control. They’re actually making things happen; they can search data, interpret data” (ITEST LRC, 2006).

—Keith Miller, Teacher Participant, Ocean Explorers (ITEST Cohort 1)

Students Are Supported in Becoming 21st Century Learners

ITEST projects combine academic STEM content and technical skill development with exposure to 21st century skills such as critical thinking and the ability to work collaboratively. Both skill sets are essential to success in the workforce of tomorrow.

“For me more and more the key is the end relevance . . . one of our primary roles is that we help paint a picture of why these activities are relevant for them and actually do have real outcomes—not just participation during those hours but part of something bigger in terms of the economy and their future” (ITEST LRC, 2006).

—Ken Ikeda, PI, Bay Area Video Coalition (ITEST Cohort 2)

Students Are Encouraged to Counter Negative Stereotypes

Many ITEST projects intentionally battle negative stereotypes that participants may harbor about themselves and their ability to succeed in life and in STEM. They do so by allowing young people to make big and interesting mistakes, offering a “safe” and judgment-free environment in which to succeed and fail, and encouraging educators to provide supportive, safe, environments where young people may feel more comfortable taking risks and assuming leadership roles.

“We’re trying to make the program work with the kids’ lives—looking, listening to barriers, real or perceived. . . . Institutionally, we learned a tremendous amount about going outside our walls—in order to be relevant.”

—Chip Lindsey, PI, Design IT Studio, ITEST Cohort 1 (ITEST LRC, IdeaBrief, 2005)

Students Are Able to Link Their Interests and Academic STEM Content to Real-World Applications

To be engaging and relevant to the lives of young people, ITEST projects foster authentic learning experiences. They give participants—students and teachers alike—opportunities to do hands-on research and other activities that have connections to STEM careers, while also developing other life skills.

Perhaps the best way to convey the impact of the ITEST projects is to listen to the voices of the workforce of tomorrow:

“I definitely want to find a scientific career that will allow me to explore my own cultural heritage.”

—Student Participant (ITEST LRC, 2007)

“I really enjoyed being able to be a part of this program and it’s one of those things that is going to stay with me for a while. It was great fun learning all the software and working with my teacher.”

—Student Participant (ITEST LRC, 2007)

ITEST projects are engaging these two potential STEM leaders—and 189,000 of their peers—in rich STEM explorations that are relevant to their lives. They are also providing these students with role models and mentors and building their teachers’ capacity to prepare them for the 21st century. In doing so, the projects offer a strategic response to the country’s “mission critical” to attract, develop, and retain the very best scientists of tomorrow, and the urgent need to mine the “untapped talent” of groups that are currently underrepresented in STEM careers and the IT industry. Taken as a whole, the diverse array of projects can serve as examples of effective STEM workforce incubators for policymakers, leaders, and educators.

Implications and Questions for Future Work

“The challenges of the 21st century can only be met by combining many skills from people with many backgrounds. America’s diversity is a clear competitive advantage if we use it.”

—(Obama 2008)

In light of this “call to action” the question lingers: What aspects of ITEST might motivate youth—particularly those from groups traditionally underrepresented in STEM fields—to pursue STEM careers? For more than a century America has been trying to make sense of how people develop and express their skills, knowledge, and interests in personally fulfilling and economically rewarding careers. Although many educators approach workforce and career development education from different perspectives, throughout this journey of discovery, career and workforce

development specialists over the last 60 years are in agreement on the following: Career development is a developmental process, shaped by experience and tempered by culture and gender.

Whether intentional or unintentional, providing STEM learning experiences in or out of school contributes to the STEM career development of youth. Engaging youth in informal STEM learning sparks their interest in STEM. Encouraging youth to enroll in STEM courses and providing support to help them achieve success in those courses can help youth persist in STEM. To reach today’s Web-connected youth, up-to-date, accurate STEM career information must be public and accessible, including information about a range of technical (non-scientist/engineer) occupations. Some of this information must directly reach out to target young women, as research on women and girls indicates that by high school females turn away from STEM career pathways. Some of it must target youth from populations underrepresented in STEM fields, whom studies show lack significant STEM role models or personal and family connections to the STEM workforce and are especially in need of support to help them connect the STEM skills they are learning in school with their own interests and values, and with potential STEM careers. All of it must capture the interest of youth, motivate them, and guide them into STEM classes and activities—preventing them from limiting their STEM career opportunities in the future. As we reflect on the ITEST experience, we see that ITEST projects are successfully addressing these challenges and guiding the STEM career development of youth.

The experiences of the youth engaged in Digispired (Digital Inspiration for Interactive Game Design and Programming Skills—ITEST Cohort 4) underscore how ITEST projects are increasing the STEM skills and knowledge of youth, building their sense of STEM self-efficacy, increasing their knowledge of the availability and rewards of STEM careers, and helping them match potential careers to their interests. In Digispired, 90 urban and rural low-income middle-school students are learning

computer programming, computer animation, and digital imaging. In the spring and summer of the past two years, youth have used Alice—a 3D programming environment—and Squeak (an open-source programming language) to develop interactive games with socially conscious themes such as nutrition, exercise, and environmental conservation and health. They have also programmed Lego robots and participated in Lego League. From these activities, the youth in Digispired have been exposed to logical thinking, communication, collaborative problem-solving, and research skills. According to parents and teachers, the project has had a profound impact on students. The students have broadened their views about STEM, expanded their thinking about STEM careers, motivated teachers in their schools to integrate Squeak and Alice in teaching, volunteered to mentor teachers who are interested in learning about Alice, and expressed interest in going to universities where they can specialize in computer graphics and game design. In Year 2 of the project, 100 percent of Digispired students decided to go to college, as opposed to 60 percent in Year 1, and 82 percent reported that they planned to pursue STEM careers. These outcomes make it clear that their ITEST experience has not just given these students a strong sense of competence in STEM career-related skills, it has helped them envision a future for themselves as STEM professionals.

“Over these two years, we have seen dramatic changes in their behavior, thought process, self-expression, willingness to take risks in making decisions, as well as increased team spirit, and motivation to build upon what they have learned.”

—Mano Talaiver, PI, Digispired, ITEST Cohort 4 (Talaiver, June, 2009)

“It is important that innovative and enrichment programs residing in Federal agencies, the informal learning community and K–20 maximize their impact by strengthening educational opportunities in STEM for all students. Programs like the ITEST Program that are designed to increase the knowledge, skills, and excitement of students to investigate and pursue careers in STEM, must include a larger pool of the underrepresented minority students.”

—Dr. Julia Clark, Lead Program Officer, ITEST, National Science Foundation (Clark, June, 2009)

The youth who participate in Digispired and other ITEST projects are representative of their peers nationwide who lack access to significant STEM role models, do not have personal and family connections to the STEM workforce, and have a history of underrepresentation in STEM fields. In opening the door to STEM careers to all youth, ITEST projects model how to craft an effective education-to-employment STEM workforce development system. By incorporating formal and informal STEM learning experiences and making use of the full galaxy of those who play an important role in youths’ career development choices, the beginnings of the model system reflect the body of research on the career development process and how to support youth’s career decision-making. If studied further, ITEST’s approach to motivating and supporting youth could help ensure that America uses its diversity as a competitive advantage.

The ITEST Program reaches deeply into underrepresented communities to explore what it takes to motivate students to persist in STEM education and STEM careers. With more than 160 projects having a significant percentage of participants from underrepresented groups and projects engaging students and teachers from various geographic regions in the U.S. including rural areas—and an ITEST COP now collecting data on important issues facing the program—ITEST has the potential to contribute to ongoing research in a significant way. The size of the ITEST program, its potential for continuation, and the commitment of PIs to collaborate

on emerging issues facing the field provide a unique opportunity to drill down into STEM diversity issues and generate data that can be mined to help answer important questions, such as:

- What are the gender specific and culturally relevant strategies that nurture interest and support persistence in engagement with STEM for specific sub-populations of youth?
- What do the career development frameworks and models look like for these sub-populations?
- Who are the influencers of youth within each sub-population and in general? How do we educate them about educational and career opportunities in STEM in ways that will increase access to these opportunities for all youth?

Studied further, ITEST's approaches to motivating and supporting youth can provide important guidelines for developing and sustaining STEM talent in our under-represented communities; with the inclusion of these communities, our nation benefits from a robust, well diversified STEM workforce.

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Working in Afterschool

Tony Streit and Wendy Rivenburgh

What is the State of the Afterschool Field with Regard to STEM?

Learning in the United States is at a critical crossroads. While debate lingers on about student performance and high-stakes testing, one aspect of educational reform once seen as optional is now regarded as a vital part of young people's lives: out-of-school time learning (Afterschool Alliance, 2008). Since the launch of the Information (now "Innovative") Technology Experiences for Students and Teachers (ITEST) Program in 2003, public acceptance of the importance of afterschool programs and government investment in those programs has steadily increased. The growing body of work on out-of-school time learning has contributed to a deeper understanding of the benefits of blending formal and informal learning and the relationship of afterschool programs to motivation, academic achievement, and educational and career pathways.

According to the Afterschool Alliance, an advocacy group for afterschool programs, about 6.5 million young people in the U.S. are actively involved in out-of-school programs run through schools and community-based organizations. These programs, prevalent in both urban and rural settings, often target the most underserved segments of the population and both ends of the political spectrum tend to support them. In 2008, the U.S. Department of Education's (ED) 21st Century Community Learning Centers (CCLC) program supported some of these programs through \$1.08 billion in federal funding.

Out-of-school programs offer a widely varying level of academic support for young people, ranging from basic remedial efforts to intensive hands-on learning. While the vast majority of programs follow a rudimentary approach—recreation, homework help, snack—many program leaders express a sincere interest in fostering meaningful linkages to the school day. For instance, a review of 21st CCLCs from 2004 to 2005 by Learning Point Associates found that more than 90 percent of programs integrated mathematics or reading, and another two-thirds of programs

offered science activities (Naftzger, Kaufman, Margolin, & Ali, 2006). In its new report, *Learning Science in Informal Environments: People, Places, and Pursuits*, the National Research Council notes that science is “receiving more emphasis in out-of-school time programs” (2009, p. 298). The authors found “a range of evaluation studies show out-of-school programs can have positive effects on participants’ attitudes toward science, grades, test scores, graduation rates, and specific science knowledge and skills” (2009, p. 178).

According to the Coalition for Science After School (2007), an affiliation of more than 100 leading science, technology, engineering, and mathematics (STEM) education intermediaries and afterschool advocates, out-of-school time offers “the kind of STEM learning that is likely to interest and motivate: less restricted uses of time and settings, strong roles for youth that encourage their participation and voice, mastering skills on individual timelines and in response to interests, mixed aged groups with the chance to mentor and tutor peers, and access to partnerships with community science resources” (p. 4).

Out-of-school time is fertile ground for STEM learning experiences. The flexibility of settings and programs after school can support young people’s interests through opportunities to explore and experiment in ways that traditional school design may not allow (Carnegie Corporation of New York, 2009). The new Carnegie Report on transforming math and science education pronounces, “Science and math content that is presented in ways that engage students in active, often cooperative work with interesting material is essential” (Carnegie Corporation of New York, 2009, p. 50). These kinds of active, collaborative learning experiences, interweaving the best of the formal and informal learning environments, dominate the teacher professional development and youth programs that are part of ITEST.

While classroom educators negotiate competing priorities that include the requirements of high-stakes testing and school reform agendas, demand for afterschool programs—sponsored by local schools, youth centers, and other community-based organizations—grows apace. Among the reasons,

providing safe, structured activities for learning, play, and service during the out-of-school hours has been demonstrated to yield positive outcomes for children and youth (Durlak & Weissberg, 2007; Policy Studies Associates, Inc., 2007).

Despite the growth in interest, weaving engaging and challenging educational content and pedagogy into afterschool programs remains an elusive goal. Most afterschool participants seek a break from “school” at the end of a day of classes (Public Agenda, 2004). Out-of-school staff may not be comfortable incorporating academic concepts or helping young people explore and inquire. As a result, many programs miss opportunities to develop science literacy, build math skills, foster design-based learning experiences, and integrate technology into other widely practiced activities, such as sports and recreation, health and safety, or community service. In contrast, afterschool educators that embrace and rise to the challenge of the integration of hands-on STEM learning open their programs to rich, multi-disciplinary learning opportunities that can inspire young people.

Several private funders have begun to channel their out-of-school time investments toward STEM learning, including the Noyce Foundation. Explains Foundation Director Ron Ottinger, “We believe that by providing large numbers of young people with engaging, quality, hands-on science, engineering, and technology experiences in out-of-school hours, we will stimulate a larger percentage to pursue STEM careers and enhance general STEM understanding and awareness” (R. Ottinger, personal communication, January 21, 2009). This is the fundamental, and compelling, rationale for the ITEST Program as well.

Various research studies have shown that engaging youth in STEM learning activities and exposing them to STEM occupations boosts interest in pursuing STEM coursework and careers. For example, an evaluation of the enrichment program GEAR UP found that program services, including a robust math-science component, improved students’ academic performance, increased graduation and college

admissions rates, and cultivated interest in STEM fields (Heisel, 2005). In their literature review on connecting informal STEM learning to career choices, Jennifer Dorsen, Bethany Carlson, and Leslie Goodyear of the ITEST Learning Resource Center point to the research of Stake and Mares (2005) who found that youth completing “a summer science enrichment program reported increased science confidence and motivation months after returning to their regular high schools. The students also reported feeling more confident in their abilities to pursue science careers” (Dorsen et al., 2006, pp. 8–9). Other programs that have been shown to change perceptions and build interest in STEM include Girls Creating Games (the precursor to the ITEST Project Girl Game Company). Designed to empower girls as technology users and producers, Girls Creating Games gives participants hands-on experience in computer programming as they design their own games. The experience breaks down gender stereotypes about programmers and, with a pair programming approach, counters assumptions that computer programming is solitary work (Denner, Werner, Bean, & Campe, 2005).

Over the last five years, a variety of ITEST projects have demonstrated approaches to facilitating intensive, highly technical out-of-school learning experiences. They often model key aspects of STEM integration—constructivist instructional practices, contextual, community-based learning, and real-world application of STEM knowledge—while intentionally engaging young people from groups that are most commonly underrepresented in the STEM workforce, such as women and people of color. These innovations can transform both the afterschool field and school-day learning overall.

Why are ITEST Projects Good Illustrations of Afterschool STEM Learning?

Whether online, or on an expedition to an urban center, a rural outpost, or the sea, ITEST projects transport learners to new domains of thought and experience.

Treading lightly on the banks of the Red River in Minnesota and North Dakota, students and teachers with the Understanding the Science Connected to Technology project (ITEST Cohort 2) collect samples of the often turbid water. They use GPS devices to record coordinates of their location and enter data into a custom designed Web-based data portal. Mud may cling to their shoes—if they forgot their waders—and their sleeves may drip a little from reaching into the water. These are the trappings of doing important water quality work within this international watershed.

Meanwhile, across the country, groups of young people and teachers participating in the Community for Rural Education, Stewardship, and Technology (CREST) project (ITEST Cohort 3) dig in the mudflats, test water quality, interview elders about access to working waterfronts, and carry out a variety of different place-based activities around islands off the coast of Maine. Students truly take on the role of researcher to investigate community questions important to them, such as “Why has the clamming industry in our town disappeared?”, “Where are the ecologically sensitive areas in our community?”, and “Where are the best spots to release larval lobsters for survivability?”

“Our projects empower students to really understand what is happening in their community and teach them how to apply this exciting technology to make change.”

—Ruth Kermish-Allen, PI, CREST, ITEST Cohort 3

These are just two examples of how ITEST projects feature robust, hands-on learning experiences that are rooted in the local community. To prepare for and follow up on their fieldwork, youth participants employ technology tools to make calculations and document what they're learning. They also search online to gather more information and participate in group discussions that build on their experiences. In these and other ways, the ITEST projects blend formal and informal learning techniques to engage STEM learners.

ITEST projects illustrate how:

- Youth are highly engaged and motivated to learn by inquiry-driven, project-based activities.
- Contextual and experiential learning activities allow young people to discover STEM concepts in their daily lives and surroundings.
- Educators benefit greatly by collaborating with local STEM experts and institutions.
- Real-world experiences and exposure to STEM professionals encourage young people to make linkages between STEM learning and careers.

Student-centered, experiential learning approaches empower educators and learners, both in and outside the classroom. An article on The George Lucas Educational Foundation's *Edutopia* website asserts that "Because project learning is filled with active and engaged learning, it inspires students to obtain a deeper knowledge of the subjects they're studying. Research also indicates that students are more likely to retain the knowledge gained through this approach far more readily than through traditional textbook-centered learning" (2008). In keeping with these promising practices, ITEST projects engage participants in STEM projects through hands-on experience wherein students and teachers work directly with the materials and tools of inquiry.

A summary of research on inquiry-based and project learning authored by Brigid Barron and Linda Darling-Hammond—and excerpted from the book *Powerful Learning: What We Know About Teaching for Understanding*—was recently published on the *Edutopia* website. In the summary, Barron and Darling-Hammond (2008) conclude that "Students learn more deeply when they can apply classroom-gathered knowledge to real-world problems, and when they take part in projects that require sustained engagement and collaboration." In addition, they report, "Active-learning practices have a more significant impact on student performance than any other variable, including student background and prior achievement" (Barron & Darling Hammond, 2008). ITEST projects are marshalling active-learning practices as they involve participants directly in formulating questions, doing fieldwork, and constructing products that reflect what they have discovered.

Another term for the approach many ITEST educators take is problem-based learning, which has been shown to foster self-directed, active learning; collaboration; and engagement and reflection (Knowlton, 2003). ITEST educators who apply problem-based learning principles encourage participants to take responsibility and drive their learning experiences, drawing on different resources to help them study problems and develop solutions.

Dr. Michael Barnett, principal investigator of the Boston College Urban Ecology and Information Technology Project, explains, "We have purposefully included technological learning tools in our inquiry framework because we want students to recognize that, through the use of technological tools, they can ask the same questions that scientists are asking, and be able to develop sophisticated answers to their own questions" (ITEST Learning Resource Center, 2006).

Working *as* scientists *with* scientists, teachers and students involved in ITEST projects endeavor to address real-world issues in ways that are deep and meaningful. The Global Challenge ITEST project, for example, con-

nects students with a network of research scientists, engineers, mathematicians, and project leaders in a long-term collaboration around possible solutions to global warming.

In our project, ‘afterschool’ meets ‘global teamwork facilitated by cyberinfrastructure’ as students learn together and compete for scholarships while working with ICT tools of science—computational science and communication tools—to tackle global warming and energy issues. The program blends science, technology, engineering and mathematics content learning, team and individual problem solving, and telementoring for high school students in an interactive website filled with global partners.”

—David Gibson, PI, Global Challenge Award, ITEST Cohort 4 (Gibson, June, 2009)

With an emphasis on engaging traditionally underrepresented groups in the STEM fields, the ITEST Program has generated a number of strategies for building participant interest. Among these are techniques to draw connections between culture and learning. Incorporating local issues, resources, and traditions honors young people’s life experiences and makes the content more relevant. The National Research Council argues that “the diverse skills and orientation that members of different cultural communities bring to formal and informal science learning contexts are assets to be built on” (2009, p. 300). Diversity—in the classroom as in the workplace—is advantageous and can help spark creativity and innovation. In the northeastern peninsula of Alaska, for example, an ITEST project called the Arctic Climate Modeling Program (ACMP) engages teachers and students from the Bering Strait School District, which serves isolated indigenous communities. The population primarily survives by subsistence living; the families must hunt and fish during the summer months so as to acquire sufficient commodities for the winter. ITEST participants are studying climatic impacts on their community, guided by field-tested curriculum that includes cultural components and native language terms. Principal Investigator Kathy Berry Bertram explains, “Native knowledge is interwoven into the curriculum to meet the needs of indigenous learners

and broaden the horizons of non-indigenous learners. Multi-generational knowledge is shared through the oral history tradition” (K. Bertram, personal communication, July 28, 2009). Community elders provide historical background and offer insights, which the young people document on video. The weather data generated by the project equipment is helpful to climate scientists, as well as to community members in their daily work. “An important aspect of the program,” Bertram emphasizes, is “that students are working directly with scientists to study the Arctic.”

Conducting fieldwork with career professionals is a key element of the ITEST Program. It is powerful for young people and teachers alike to carry out authentic research in their communities. Many ITEST projects employ what is known in the afterschool field as a “positive youth development model,” in which youth are engaged in activities that are meaningful to them, that teach them skills linked to post-secondary education or employment, and that provide opportunities for leadership and engagement with the wider community. They have opportunities to exercise influence and make decisions, and their capacity to manage their own learning and life choices expands (The Forum for Youth Investment, 2003; Gambone, Yu, Lewis-Charp, Sipe, & Lacoe, 2004; McLaughlin, 2000). In this type of programming, youth are given the “opportunity to work through real world activities that demand their full participation” (Dimitriadis, 2001).

To facilitate participants’ learning experiences and exploration of career pathways, ITEST projects partner with local businesses and create unique opportunities for carrying out STEM activities that have real-world applications. ITEST’s focus on workforce development, an aspect largely missing in afterschool programs, is one the field appears highly suited to embrace, particularly as it relates to connecting young people with STEM professionals as mentors. In recent years, researchers have recognized this rich—as yet untapped—potential for youth programs to prepare young

people for the workforce (Cochran & Ferrari, 2009; Schwarz & Stolor, 2006). For example, in their 2009 article on preparing youth for the 21st century, Cochran and Ferrari assert that “the time is right for youth programs to consider a more intentional role in supporting adolescents’ workforce preparation. Youth development and workforce preparation are really two sides of the same coin” (p. 21).

How are ITEST Projects Demonstrating the Power of Blending Formal and Informal Learning?

One of the model practices that has coalesced through the ITEST Program is connecting and leveraging the promising practices around STEM learning found in both formal and informal learning environments. Contextualizing learning in young people’s lives and providing opportunities for them to apply their knowledge and skills in their communities represent fundamental examples of how informal learning strategies can complement and enrich classroom teaching. In their recent article, Cochran and Ferrari cite the findings of the Partnership for 21st Century Skills (2003) on the important role that “authentic learning experiences” play in learning. They note that, “The authentic learning experiences provided by youth programs can help reduce boundaries between formal and non-formal education . . . thereby connecting the various contexts of adolescent life” (Cochran & Ferrari, 2009, p. 16).

In informal learning environments, young people have a lot of latitude to identify problems that they want to solve and to be truly creative users of STEM knowledge. Learner-driven inquiry, in which teachers and students define and explore their own questions, is a hallmark of the ITEST experience, and an important element in kindling excitement about STEM careers. For example, the authors of *Learning Science in Informal Environments* report, “Several case studies of community science programs . . . document participants’ sustained, sophisticated engagement with science and sustained influence on school science course selection and career choices. In these programs, children and youth play an active role

in shaping the subject and process of inquiry” (National Research Council, 2009, p. 304). In their investigations of students’ experiences with STEM content and careers, a team of researchers led by Helen Madill “found that applications of STEM to real-world problems help sustain students’ interest and engagement in STEM coursework, and ultimately their persistence in post-secondary STEM study” (2004, as cited in Dorsen, Carlson, p. 11). An ITEST project based in northern California, Build IT (Cohort 3) partnered with Girls Incorporated to reach and engage young women in information technology (IT) activities and career exploration. With an established network of more than 1,000 sites and a commitment to empowering girls through intensive youth development programming, Girls Inc. was a natural fit for the work that SRI International was undertaking to transform girls’ experiences with IT.

Key elements of this project include hands-on learning, teamwork, field trips, and interactions with career professionals, as staff seek to give girls “real experiences designing and developing information technologies,” according to Principal Investigator Melissa Koch (M. Koch, personal communication, January 16, 2009). As part of the process, participants test the websites and interactive games they create with real users. One of the girls commented, “When you see other people playing your game, you feel really accomplished” (WGBH Educational Foundation, 2009). Having a real audience makes the learning experience more authentic and is a compelling demonstration of the power of approaches not traditionally associated with classroom teaching.

Informal learning experiences are layered and complex, requiring the contributions of talents and expertise from multiple sources (learner, educator, community, etc.). ITEST projects illustrate the value of innovative models in which youth and adults function as equals and partners, learning and working together. Sharing in real-time research and practicing hands-on science collaboratively with scientists and technology professionals engage young learners in authentic STEM work.

Inquiry-based, experiential learning is inherently motivating for young people and requires their ongoing engagement and contribution of ideas and skills. In its report *Every Child Learning: Safe and Supportive Schools*, the Learning First Alliance reflects on the powerful benefits of this form of learning, stating: “Students are most motivated to learn, feel the greatest sense of accomplishment, achieve at the highest levels when they are able to succeed at tasks that spark their interest and stretch their capacities” (2001, p. 4). They continue: “To be meaningful, learning must effectively connect to students’ questions, concerns, and personal experiences, thereby capturing their intrinsic motivation and making the value of what they learn readily apparent to them” (Learning First Alliance, 2001, p. 4). Involving young people as drivers of their own learning process honors their prior knowledge and cultivates their natural curiosity.

Indeed, the best informal learning practices promote the development of skills that students can use throughout their lives—both in and out of school—and build self-sufficiency and a sense of ongoing discovery that can be applied in all walks of life. ITEST educators are demonstrating the numerous ways that these practices can be brought to bear, to deepen and enrich young people’s education in the STEM fields and beyond.

Having reached this milestone in the tenure of the ITEST Program, the question begs asking: *How do we leverage the ITEST experience of learning in informal settings to cultivate our nation’s next generation of STEM professionals?* Because ITEST projects offer compelling examples of afterschool STEM learning and demonstrate the benefits of blending formal and informal learning, the ITEST community is well-positioned to answer a number of critical research questions, such as:

- What characteristics are central to a STEM workforce development approach in afterschool?
 - How critical is the role of STEM professionals as facilitators and mentors?
 - What is the role of the educator vs. peer-to-peer learning?
 - What are the effective ways to coordinate with and use resources of the community?
- The ITEST community is also poised to address questions on impact and scalability, such as:
- What do we know about how successful these programs are at guiding young people toward STEM careers?
 - What program design elements most contribute to these outcomes?
 - How can these kinds of experiences be replicated in a fashion that is scalable and sustainable for afterschool programs?

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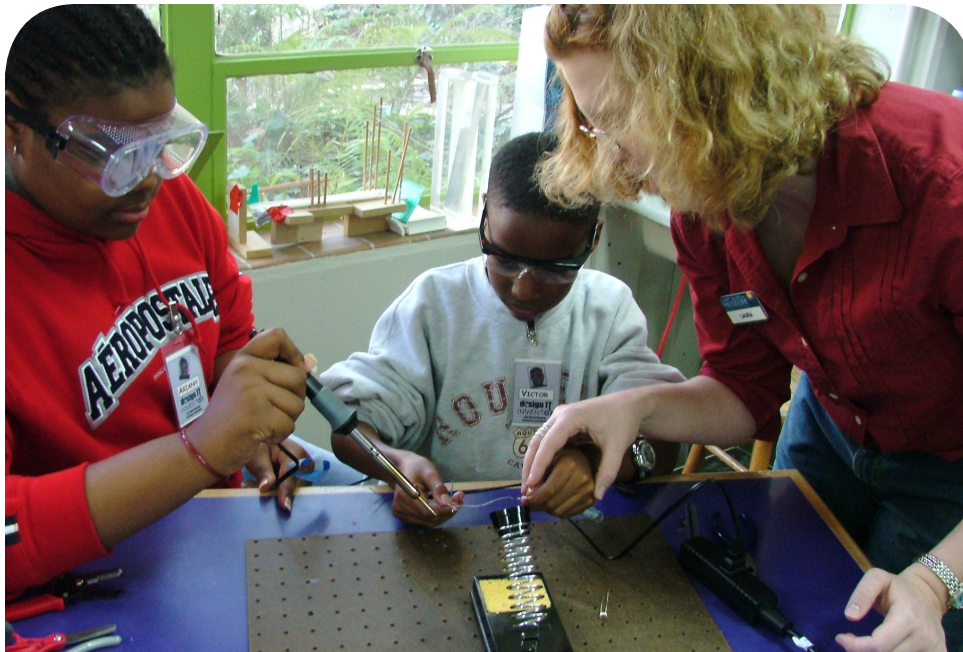
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ITEST Teacher Professional Development: Distinctive Implementation of Best Practices

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In 2007, a small group of Innovative Technology Experiences for Students and Teachers (ITEST) principal investigators (PIs) and Learning Resource Center (LRC) staff conducted an online survey of the PIs of all ITEST teacher education projects from Cohorts 1 to 4, accompanied by in-depth interviews of nine PIs. The results of the exploratory study helped to clarify those components of professional development that the PIs identified as being most important in their work. While exploratory in nature, when looked at in combination with project artifacts and LRC documentation, the results highlight the distinctive ways that ITEST projects provide innovative STEM professional development to teachers.

What Is the State of STEM Teacher Professional Development?

The field of science, technology, engineering, and math (STEM) professional development has identified an extensive, and sometimes overlapping, set of components or “best practices” that can be used in the design of effective professional development. Guskey (2003) reviewed key components of successful professional development from 13 different academic sources, and found among them more than 20 components. Some of the more commonly identified components are enhancing teachers’ content and pedagogic knowledge (Ehman, Bonk, & Yamagata-Lynch, 2005; Garet, Porter, Desimone, Birman, & Yoon, 2001; Guskey, 2003), providing sufficient time and resources (Ehman et al., 2005; Garet et al., 2001; Guskey, 2003; Penuel, Fishman, Yamaguchi, & Gallagher, 2007), promoting collegiality and cooperation (Ehman et al., 2005; Garet et al., 2001; Guskey, 2003), and coherence with other learning activities (Garet et al., 2001; Guskey, 2003; Penuel et al., 2007).

Of particular relevance to ITEST, researchers have found that effective professional development imitates the kinds of teaching that it promotes. If the professional development focuses on inquiry and technology in the classroom, then it should give teachers hands-on opportunities to engage in inquiry and to use technology (Basista, Tomlin, Pennington, & Pugh,

2001; Easton, 2008; Linn, 2003). This helps teachers to become learners and better understand the learning experiences of their students (Loucks-Horsley & Matsumoto, 1999; Peck, Barton, & Klump, 2007). Professional development activities must also help teachers understand the interaction between information technology (IT), related content, and pedagogy (i.e., technological pedagogical content knowledge) (Bednarz, Acheson, & Bednarz, 2006; Ertmer, 2005; Ferdig, 2006; Koehler & Mishra, 2005; Mishra & Koehler, 2006).

How Do ITEST Projects Build Teacher Capacity to Bring IT into the Classroom?

By instituting certain essential tenets of best practices in professional development, together with innovative ways of implementing those best practices, ITEST teacher professional development projects have successfully worked with more than 3,000 teachers across the country. The teachers have a range of experiences, and ITEST projects help them improve their IT skills and innovatively integrate STEM into their classrooms.

While ITEST PIs concurred with many of the components of “best practices” as described in the literature, they also described important elements of their projects that have distinctive features not generally identified in the literature. Among the distinctive features of ITEST projects are including youth in the professional development process, promoting the innovative application of STEM technologies, and making STEM career connections for teachers and students (see *ITEST and Workforce Development* on page 8). These unique features of ITEST professional development projects were included in the original RFP, are thus integrated in all the projects, and have emerged as fundamental aspects of the ITEST experience.

The sections that follow synthesize six key features—“best practices”—of ITEST professional development projects, as described by their PIs and in project literature. The first four—collegiality and collaboration; coherence and relevance to teachers’ experiences; active learning by teachers; and

technological pedagogical content knowledge—are commonly identified as elements of effective professional development. The last two—youth involvement and STEM career connections—are largely absent from the literature on effective professional development and are used in particularly unique ways in ITEST projects.

Collegiality and Collaboration

“These 10 teachers now get together all the time . . . You’re at one school district. Ten teachers didn’t know each other. They now all know each other so that this relationship is going to continue well beyond when I go away . . . They now have the contacts and they see the benefit of community. You can bounce ideas off of other people. You can try things. You can lobby together. A group of 10 people has a lot more power than one.”

—from PI interviews

All ITEST projects’ professional development emphasizes collegiality and collaboration (Ehman et al., 2005; Guskey, 2003; Loucks-Horsley, Love, Stiles, Mundry, & Hewson, 2003), which is the degree to which a professional development program facilitates teachers working together, sharing ideas, and building a sense of community. In particular, many ITEST projects created or expanded “communities of practice” (Barab, Barnett, & Squire, 2002; Barab & Duffy, 2000), which provide a space for teachers to learn new knowledge and skills in their work places and regularly share ideas and issues with colleagues beyond professional development events. Communities of practice can increase teachers’ knowledge, skills, and confidence. Several ITEST projects described creating or expanding communities of practices.

Another reported, “[The ITEST] team becomes very much a leadership piece within their schools; where they really have become this little seat of knowledge that other teachers and other students are coming to, to say I want to be part of this. How can I integrate it into my classrooms?”

Thus, ITEST teacher projects encourage teachers to develop communities of practice in their own local areas. At the same time, the National Science Foundation (NSF) ITEST Program has provided a space for ITEST PIs, evaluators, and others to develop their own community of practice. This mega-community of practice is described in greater detail elsewhere in this document (see *The ITEST Community of Practice: Lessons and Implications* on page 55).

Coherence and Relevance to Teachers' Experiences

“Coherence,” or the alignment of professional development with content, is a key component of the ITEST projects' approach to professional development. Penuel et al. (2007) noted “teacher perception of the coherence of professional development” as one of two key elements in their study. According to Garet et al. (2001), one aspect of coherence is the extent to which a professional development program emphasizes content and pedagogy aligned to curricular standards. All surveyed projects placed high (88 percent) or moderate (12 percent) priority on aligning their materials and activities with regional, state, or national standards.

Active Learning by Teachers

ITEST projects are designed for teacher participants to engage in active learning, including meaningful discussion, planning, and practice. For the first five ITEST cohorts, all ITEST teacher education projects included informal education summer “institutes” with youth from the local community. During these institutes, teachers had an opportunity to try out new knowledge and skills without typical classroom pressure and with the support of project staff. As one PI noted, “. . . the idea here is for the teachers really to practice to sort of experiment with how it is that I can best teach my students to use this tool.” ITEST teacher education projects also prioritize actively involving teachers in developing IT-based classroom materials.

Eric Klopfer, PI of New Mexico Adventures in Modeling (ITEST Cohort 1), argued that teacher professional development must reflect the learning style you want to teach: “The best way is to train teachers to go through the same process as the way youth learn technology. . . . teachers learn through working as their students would. Facilitators also play the role of learners.” This method, he explained, includes “modeling real scientific practice through simulated systems, modeling classroom practice (case studies), creating many ways to do this successfully in the classroom, creating a comfortable environment, and creating a community of learners . . . Everyone models a new system and learns together—teachers and students as co-learners.”

Technological Pedagogical Content Knowledge

Technological pedagogical content knowledge (TPCK) refers to the unique knowledge and skills that enable the application of appropriate technology and pedagogical strategies to the teaching of specific content (Bednarz et al., 2006; Ferdig, 2006; Koehler & Mishra, 2005; Mishra & Koehler, 2006). Although PIs did not explicitly identify TPCK, they described key aspects of TPCK as critical elements of their projects. For example, many PIs emphasized that the development of IT skills in isolation would not achieve the overall goal of integrating cutting-edge technology into classroom teaching unless accompanied by a focus on subject-matter content and how children learn. All PIs noted that the effective integration of cutting-edge technologies in the classroom requires that teachers develop the necessary IT skills and that they make a shift in pedagogy toward inquiry learning. As stated by one PI, “I wouldn't separate the technology from the pedagogy, because you really can't. You don't do pedagogy in a vacuum.” Another noted, “Software is great and it's wonderful, but it's the software with the pedagogy that makes the difference. The greatest software in the world isn't going to teach itself.”

“It’s very important for our teachers that they’re doing real science, that this science will lead to answering a real question. They generate DNA data that is unique . . . We try to provide teachers with this authentic science and IT experience—working on applied IT skills.”

—Simona Bartl, PI of Marine Biotechnology and Bioinformatics, ITEST Cohort 3

Youth Involvement

All ITEST teacher education projects include at least a week in the summer when teachers “practice” with youth in the context of a summer institute, a less formal setting than the classroom. This version of active learning distinguishes the ITEST professional development model from traditional professional development, which tends to separate the professional development with teachers from the classroom and students. Teachers are freed from the classroom constraints of accountability, and the ITEST project stays connected to the overall goal of professional development—increased student interest and involvement in STEM. The youth involvement allows teachers to work with them in a collaborative setting, where the youth can contribute to teacher understandings of technology, pedagogy, and content. One PI noted, “We really try to create in our summer institutes a learning environment that’s very non-hierarchical, where we have students and teachers learning together, where students become teachers in many cases.”

STEM Career Connections

The review of project artifacts (proposals and project descriptions) confirmed that all ITEST projects featured IT careers in their student materials and/or activities. In the questionnaire, 83 percent of surveyed projects noted the importance of interacting with IT professionals, 75 percent mentioned providing IT college/career information, and 49 percent mentioned having IT mentors. Specific activities included bringing in career speakers, holding career fairs, visiting local businesses, and offering internships. One project worked with local businesses to identify marketplace problems and integrated these problems and related workforce skills into their IT-based math curriculum. While literature on effective professional development components does not typically mention careers, our data indicates that these connections can be very powerful. As one PI noted, “We took the teachers and the students to a power company that was not too far from the site where we’re holding this event. One of the senior managers of the plant, who was conducting the tour, looked at the teachers after they finished and said, ‘I just need for you to understand that we have jobs, not low-paying, low skill jobs, but technical positions, managerial positions, middle-level management positions at this company. We would love to hire your students, but, by and large they’re not qualified.’ A lot of the teachers really raised their eyebrows when this person said that.”

Connections with STEM professionals are also an important extension of communities of practice. While several researchers point to the need to expand teacher communities beyond school boundaries to include partnerships with practitioners in science, math, engineering and technology (Davis, Petish, & Smithey, 2006; Loucks-Horsley & Matsumoto, 1999; Vrasidas & Glass, 2005), ITEST projects placed particular emphasis on this and made significant efforts to link students directly with career information, activities, and professionals.

Conclusion

While they emerge from an exploratory study, and not an exhaustive summary of ITEST professional development projects, our findings provide insight into the distinctive components of ITEST teacher education projects. As described by their PIs, these projects embody many of the characteristics of effective STEM teacher professional development commonly cited in the literature. As ITEST moves forward, projects are making vital contributions to the field's knowledge base by producing new data on the efficacy of two innovative features—involvement of students and an emphasis on STEM career connections—rarely found in STEM professional development. These two features appear to have a significant potential to support transformations in STEM teaching and learning, and they warrant further study to answer a series of key questions that has the potential to significantly enhance STEM PD:

- What impact does youth involvement have in professional development across all ITEST projects?
- How do students' roles as teachers in ITEST teacher education affect their sense of self-efficacy and consideration of STEM careers?
- Across all ITEST projects, how do the partnerships between ITEST teachers and STEM professionals appear to support teachers' ongoing learning?

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ITEST Evaluation: It's About Building Capacity

Leslie Goodyear

Introduction

Evaluation is important both for learning about what works and how, and for demonstrating the effects of programs or interventions. Innovative Technology Experiences for Students and Teachers (ITEST) projects are required to conduct formative and summative evaluations of their three-year initiatives. Through their evaluations, they collect information that promotes continuous improvement and demonstrates the value of their projects with regard to targeted outcomes.

ITEST projects approach evaluation from various points on a developmental continuum. Some are very new to project evaluation, while others have a great deal of experience with project and program level evaluation, funded by the National Science Foundation (NSF) and through other grants. In addition, the evaluators who are hired by ITEST projects vary in their experience in the field of evaluation; in their knowledge of STEM programs and projects; in their understanding of NSF programs and their evaluation requirements; and in the approaches and methods they choose in conducting evaluations.

The ITEST Learning Resource Center (LRC) built evaluation capacity among ITEST projects and supported project evaluation. The LRC offered a menu of technical assistance events and community opportunities such as networking; the development of an evaluation community of practice (the ITEST COP); content-specific technical assistance; evaluation management technical assistance; online resources and peer exchanges; and one-to-one expert consultation.

This article illustrates the evaluation capacity building (ECB) work of the ITEST LRC. Later in this article, there will be a brief description of ways in which ITEST projects developed evaluation capacity through working with the LRC. Two projects examples are provided: The SPIRIT project worked very closely with their evaluator to generate useful data to guide project decision-making and to demonstrate project outcomes. The Technology at the Crossroads project participated in an LRC-facilitated research working group that brought capacity and knowledge back to their project work.

What is Evaluation Capacity Building (ECB)?

Evaluation capacity building (ECB) providers advance important evaluation goals by helping programs develop systems for collecting evaluative information. They also support programs in maintaining programmatic cultures that promote evaluative thinking.

ECB is undertaken through a variety of methods and with a range of goals (Milstein & Cotton, 2000). The most cited definition of ECB, developed by Baizerman, Compton, and Stockdill (2002), is: “the intentional work to continuously create and sustain overall organizational processes that make quality evaluation and its uses routine” (p. 1). Milstein and Cotton outlined five main elements of evaluation capacity: motivational forces; organizational environment; workforce and professional development; resources and support; and learning from experience (2000, p. 3). They also identified two additional key points regarding evaluation capacity: that “capacity is always relative to the task in question” and “elements of capacity are interdependent” (2000, p. 3). They distinguish evaluation capacity—“the ability to conduct an effective evaluation” (p. 1)—from the ways in which conducting evaluation builds other capacities, such as the capacities of “individuals, organizations or communities to achieve broad social goals . . . Evaluation activities might facilitate such community capacity through the benefits of participatory methods and through the use of findings that reveal whether programs and policies are having their intended effects” (p. 1).

What is the State of the Field with Regard to ECB, Specifically Related to Science, Technology, Engineering, and Math (STEM) Programs?

The recognition of the value and importance of program evaluation, particularly as it contributes to program understanding and improvement, has led to a growing interest in helping organizations, programs, and projects improve their ability to conduct evaluations and apply the findings to their

work. ECB is a relatively recent topic of interest within the evaluation field (Cousins, Goh, Clark, & Lee, 2004).¹ Since the late 1990s, a growing body of evidence has highlighted effective approaches to ECB (Huffman, Lawrenz, Thomas, & Clarkson, 2006; King, 2005; Preskill & Russ-Eft, 2005) and underscored why ECB is important (Baizerman, Compton & Stockdill, 2002; King, 2002; Preskill & Russ-Eft, 2005). The ECB work of the ITEST LRC has been directly influenced by this body of work.

What has been the NSF’s Role in Building Evaluation Capacity?

According to Katzenmeyer and Lawrenz in the Spring 2006 edition of *New Directions for Evaluation* on the topic of STEM evaluation, “Three key issues have underlined NSF’s policy regarding education evaluation: (1) the question must drive the methodology, with each evaluation expected to adhere to standards of evidence relevant to the approach chosen to answer the question; (2) there is a shortage of well qualified evaluators for STEM (science, technology, engineering, and mathematics) education projects and programs; and (3) there is a serious lack of instruments of demonstrated validity and reliability to measure important outcomes of STEM education interventions, including teacher knowledge and skills, classroom practice, and student conceptual understanding in mathematics and science”(2006, p. 7). Given that the question must drive the methodology, as noted in item 1 above, and that “capacity is always relative to the task in question” (Milstein & Cotton, 2000, p. 3), it is impossible to take a one-size-fits-all approach to designing or conducting evaluations on the project or even program level.

¹ A scan of the American Evaluation Association (AEA) programs for the years 2004–2006 shows that in 2004 there were 10 conference sessions dedicated to ECB, in 2005, 16 conference sessions focused on ECB, and in 2006, at least 28 sessions highlighted ECB and issues related to it. At the AEA conference in 2007, close to 50 sessions featured presentations on ECB.

The imperative to customize evaluations to fit initiatives' unique goals and contexts is not the only key consideration in designing and conducting evaluations. There is also a significant need—identified in all of our work with NSF-funded programs as well as noted in NSF-funded evaluation meetings—for technical assistance and capacity building to support basic project evaluation efforts. To address evaluation capacity needs, project PIs need skills to hire and contract with evaluators, to manage evaluation efforts, and to use evaluation data and findings. Evaluators need increased capacity to meet the complex evaluation needs and level of rigor that NSF-funded projects and programs demand.

To address evaluation capacity needs, NSF has engaged in a number of programs and projects with the goal of evaluation capacity building for STEM programs. As noted by Huffman et al. (2006), “previous ECB efforts . . . have created training opportunities in STEM evaluation, but the field of STEM evaluation needs a more comprehensive model of ECB. Overall, there is a need for evaluation training programs to move beyond a training view of evaluation capacity building, to include long-term activities and experiences . . .” (p. 75). The ITEST ECB work is in response to this need, and in the context of the NSF capacity building work.

What Has the ITEST LRC Done to Develop Evaluation Capacity among ITEST Projects?

The ITEST LRC's ECB Philosophy

As with other technical assistance provided by the ITEST LRC, the evaluation technical assistance is primarily responsive to project requests and articulated needs. Through regularly occurring contact with ITEST projects and scans of the field and the broader context in which these projects operate (e.g., NSF requirements, current notions of scientific rigor and relevance, new developments in evaluation), the LRC determines the evaluation content that would best support ITEST projects' evaluations. Many evaluation technical assistance events or products—including the

reporting to NSF event, and the online evaluation instrument database—have come directly from comments or suggestions from ITEST project PIs. In the first year of the ITEST Program, the LRC began to receive calls from projects that needed evaluation resources, advice, and assistance with evaluative decision-making. Heralding the issues that would challenge ITEST projects in conducting and managing evaluations, these early technical assistance requests helped form the structure for the coming years' evaluation technical assistance.

The ITEST LRC's Evaluation Technical Assistance

The LRC offers the following specific evaluation technical assistance:

- Just-in-time individual project evaluation technical assistance, answering questions about evaluation management, expectations, and what we call “evaluation marriage counseling.”
- A yearly “evaluation peer exchange”—a moderated listserv where evaluators and project PIs can ask questions, share information, and troubleshoot common issues in evaluation.
- Conference call and webcast “live” technical assistance events, targeting any and all evaluators, PIs, and program staff in the ITEST community. Topics have included cultural competence in evaluation, using evaluation findings, measurement issues in ITEST projects, evaluators and PIs getting along, etc.
- Opportunities to present evaluation findings and discuss evaluation issues and challenges at the annual ITEST PI meeting.
- An annual conference call to help projects understand the NSF reporting requirements and how evaluation findings can support their annual reports.
- The development of an online, searchable evaluation instrument database, including instruments from projects and guided by a community understanding of fair use.
- Coordination of publication opportunities and presentations at the conferences of organizations such as the American Evaluation Associa-

tion (AEA), the American Educational Research Association (AERA), Society for Information Technology & Teacher Education (SITE), and the National Science Teachers Association (NSTA).

What are the ECB Outcomes for ITEST Projects?

ITEST projects' evaluation work appears to have been significantly strengthened by the LRC's ECB efforts. For example, the SPIRIT project (ITEST Cohort 3) participated in the Embedded Evaluation Working group. This was a group of project evaluators and investigators who were interested in exploring ways in which evaluation activities could be embedded in the activities of the program. As a result of SPIRIT project staff's participation in the group, they developed embedded evaluations to use in their project, and the ITEST evaluator and PI worked closely together to use the information to inform the project. For the Technology at the Crossroads project (ITEST Cohort 2), the ITEST evaluator and the PI of the Technology at the Crossroads project cooperated to ensure that the evaluation was contextually sensitive and that the measures were informing project decision-making.

In both projects, activities were designed so that students would not be aware that they were being evaluated. For example, the Technology at the Crossroads project used the following activities:

- **Name that Tree**—Students worked with their team to correctly identify five trees in a local park. Trees were labeled with white laminated tags. When the researcher said "Go" teams split up and tried to identify the labeled trees. The objective of this game was to demonstrate that teams could identify trees in the real world.
- **GBTI Gallery**—Students worked with their team to inventory a tree as accurately and quickly as possible using Greater Boston Tree Inventory categories. The objective of this game was to demonstrate that teams could use ArcPad GIS software and their PDA to collect data in the real world.

- **Multicache Mayhem**—Students worked with their team to complete a multicache course (consisting of three locations) as quickly as possible using GPS units. The objective of this game was to demonstrate that teams could use a GPS unit to navigate an urban environment.

"Past reports and presentations for Technology at the Crossroads . . . provide evidence of the strong collaborative relationship between the project and evaluation teams. The project team, for example, has been responsive to evaluation results and recommendations throughout the three-year project, often using results to make decisions about the continued development of the project. Similarly, the evaluation plan and methods were revised over time in response to feedback from the project team. The collaborative approach used to develop authentic assessments for this project, in particular, has benefited both the project and the evaluation, resulting in a contribution to the ITEST community in particular and the field of evaluation in general." (Goodman Research Group, Inc., 2008)

Other projects, such as Salmon Camp (ITEST Cohort 1) and the SUCCEED Apprenticeship Program (ITEST Cohort 3), have intentionally built evaluation capacity within their project teams and promoted a culture of evaluative thinking by taking two specific actions:

- Including the organization's internal evaluators on the team and gradually turning over participatory evaluation strategies to field staff members after modeling them (such as conducting student interviews, performance assessments, and electronic surveys).
- Involving staff members in ongoing assessment of student learning, instrument development, and the use of evaluation results to make program decisions.

Implications and Questions to Guide Future ECB Work

In a number of ways, the ITEST ECB work is different from other ECB work discussed in the literature. First, there is no mandate for the projects to participate in the evaluation technical assistance offered by the LRC, and there is no standard that must be met in terms of project evaluation. In other cases, ECB programs are implemented to bring staff up to a certain level of understanding of evaluation or to have a specific level and types of evaluation implemented in an organization. For the ITEST projects, the technical assistance provided by the LRC is supplemental; it is there if a project needs it, and the assistance is tailored to project needs.

In addition, because of the technology focus of the ITEST Program, the ITEST LRC uses technology tools to conduct its technical assistance—including the evaluation technical assistance. There is not much in the literature regarding the implementation of ECB through technology, such as online resources, listservs, and virtual community building.

And last but not least, a main component of the ECB as developed by the ITEST LRC is to create an ITEST evaluation community of practice (see *The ITEST Community of Practice: Lessons and Implications* on page 54). Creating a network of evaluators who can, and do, support each other through sharing resources, offering advice and support, and creating products together is a contribution not just to the ITEST community at large, but to the library of ECB approaches. This peer-to-peer ECB is a strong complement to the just-in-time and event-based expert support model.

Continued research on evaluation capacity building can address important questions such as the following:

- How do communities of practice develop the evaluation capacity of the members of the community?
- What role does technology play in developing evaluation capacity through technical assistance and communities of practice?
- What is the relationship between ECB work and projects' capacity to deliver on outcomes?

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The ITEST Community of Practice: Lessons and Implications

Siobhan Bredin and Ardice Hartry

Throughout the first five years of the Innovative Technology Experiences for Students and Teachers (ITEST) Program, the ITEST Learning Resource Center (ITEST LRC) has worked in collaboration with project principal investigators (PIs), staff and evaluators, and National Science Foundation (NSF) program officers to build and nurture a community of practice (COP). In addition to supporting and strengthening the work of individual ITEST projects in communities across the United States, the ITEST COP benefits the larger field of science, technology, engineering, and math (STEM) workforce development through synthesis and dissemination of the new knowledge generated across the program.

The ITEST COP:

- Facilitates knowledge sharing, generation, and synthesis across the program, which has resulted in events, products, and publications that inform the field.
- Provides practical support for PIs, staff, and evaluators in addressing challenges that strengthens the overall work of the program.
- Encourages long-term collaboration that has resulted in funding to sustain and expand work.

What Is a Community of Practice?

The term *community of practice* came into widespread use from the work of Lave and Wenger (1991), who wanted a way to describe learning through social participation, where “participants share understandings concerning what they are doing and what that means in their lives and for their communities” (p. 98). These communities foster mutual engagement among the members, while they work on a joint enterprise using a shared repertoire of terminology and skills (Wenger, 1998).

All communities of practice share the following characteristics:

- Participants connected by common goals and interests.
- Active participation and leadership by members.
- Encouragement and support in order to thrive.

In the field of education, the concept of a community of practice has been applied regularly to professional development models. For example, the concept of learning within a social environment has been viewed by one author as a way to overcome some of the challenges of professional development, including “the separation of research and practice, the isolated nature of teaching, weak or poorly articulated theoretical frameworks, and the lack of consensus about the goals of education and what constitutes recommended practice” (Buysse, Sparkman, & Wesley, 2003, p. 266). In addition, professional developers view communities of practice as a way to bring together educators with different levels of expertise to share their skills and experiences and thus increase the knowledge base for the field as a whole. In many ways, the idea of a community of practice applies well to the work of the LRC, which strives to bring together the disparate projects of the ITEST Program into a collaborative environment and to connect “what we know” with “what we do.” In the absence of individuals who function as “knowledge-builders” (Hartnell-Young, 2006), the LRC has encouraged contributions to the pool of knowledge, taken responsibility for others’ learning, and made connections among projects.

Building upon the expertise and interests of project PIs, the LRC uses a collaborative and supportive approach in facilitating and nurturing the ITEST COP, similar to the guiding principles outlined by Parsons in her article on Communities of Learning, Inquiry, and Practice (CLIPs) (2009), “The CLIP guiding principles are designed to promote caring, creative, and energizing ideas and actions that benefit the common good and work along side formal policies that grow out of the institution’s more controlled approach to change” (p. 49).

Is There an ITEST COP and, If So, How Does It Benefit the Work of the Program?

Communities of practice work well and are sustained when they create value for individual members and when members feel that they get something out of participating in the activities. While some of this added value may come from sharing information, much comes from the ability to “think together” in order to consider issues and create common solutions. Findings of the LRC Years 1–4 evaluation report revealed what members of the ITEST COP acquire through participation, what keeps them active, what retains their interest, and what gets them thinking in ways that move their work—and the field—forward:

1. *Opportunities to Learn from Each Other*

ITEST PIs and evaluators have expertise in education, STEM content, youth development, teacher professional development, diversity/equity, and partnerships. The community structure provided by the LRC has provided multiple opportunities to learn from each other, share success strategies and challenges, and partner together on related work.

2. *Authentic Experiences*

Survey results and interviews indicate that many ITEST project personnel felt a sense of belonging to a larger ITEST community. Working toward the same goals and sharing similar challenges helped build that sense of community. One of the elements of a community of practice is the importance of “authentic experiences”—opportunities to solve real problems and to work together on real challenges—and finding ways to offer these experiences was one of the biggest challenges for the LRC. To this end, the research working groups served as a vehicle to bring together members of the ITEST projects—sometimes PIs, sometimes evaluators—to solve problems and develop a common research agenda.

3. *Multiple Connection Points*

The LRC's flexibility—its willingness to try new ways to communicate with projects and to listen to project suggestions in order to improve technical assistance offerings—has been key to its success in building a community of practice. Projects have been able to choose from a variety of items the ones that best match their needs. This semi-tailored approach to technical assistance and other offerings proved to be successful. For every PI who said that a publication was not relevant to an individual project, or failed to provide new information, another PI would say that it was very useful or interesting. A one-size approach does not fit all in the world of technical assistance, especially assistance offered to such a varied group of projects. Yet the overall levels of satisfaction with the resources and offerings, evident in survey and interview responses, suggest that the LRC has managed to find a way to meet project needs in an efficient manner.

What Lessons from the LRC's Creation and Ongoing Nurturing of the ITEST COP Can Inform the Work of Other Programs, Initiatives, and Learning Communities?

Members of the ITEST COP who had participated in one or more call or webcast found the event useful and helpful or an otherwise positive experience. Some calls were useful because they provided “helpful nuggets” of information, while others were just “inspiring.” As with many other events offered by the ITEST LRC, one of the most important outcomes of the calls was the perception that projects were part of a community. As one PI said, “It’s a powerful thing to know that you’re not alone—that is the important thing that I get out of [the calls].” (MPR Final Report, 2008)

The ITEST COP, nurtured and encouraged by the LRC and supported by the leadership of individual members and groups, has enabled participants to: work towards common/related goals; share challenges and strategies openly

within the community; gather, synthesize, and disseminate work and learnings to a wide audience; and extend and expand support for ongoing work. The following success strategies for creating and nurturing communities of practice emerge from the ITEST COP's experiences:

1. *Employ a Collaborative Approach and Encourage Leadership*

Identify, acknowledge, and build off the expertise and interest of community members—in this case, project PIs, staff, and evaluators—to create a mixture of events hosted/proposed by projects, the LRC, and the NSF. Through individual relationships established between LRC liaisons and project PIs, supplemented by online questionnaires, and the annual summit (face-to-face meeting), expertise and interest are identified and community leaders emerge. Through a PI Emeritus program, project staff are encouraged to continue participation in the community after their program funding has come to an end. In addition to continued knowledge sharing, participants in the ITEST community have had opportunities for publication and additional funding (for example, members of the teacher change topical working group applied for and received funding to conduct research in this area).

2. *Be Intentional in Planning and Coordination*

Coordinators are key to a community's success (Wenger, McDermott, & Snyder, 2002). LRC staff focus on planning for, coordinating, and nurturing the community through annual technical assistance plan development and implementation, yearly in-person meetings, and individual interactions between liaisons and project staff. Communities of practice are not easy to sustain, especially if the members do not interact on a regular basis. The literature suggests that online communities that function as open-ended forums have a harder time retaining members than those that focus on a specific task or topic. This perception is supported by the LRC's findings, as the more popular online events, such as the Evaluation Peer Exchanges, are very specific and concrete in nature and have resulted in the creation of an ITEST online evaluation instrument database available to all community members.

3. *Provide Infrastructure and Multiple Connection Opportunities/Methods*

The LRC provides infrastructure and an organizing framework for the ITEST COP. Through use of an internal private online community that includes both general and topical online discussion lists, a virtual meeting space, and archives of events and publications, participants can easily communicate with each other and access materials as needed. Group events are offered throughout the year in a variety of formats including webcasts, conference calls, online discussions, and an annual face-to-face meeting. Publications from each event are available within two weeks of the event. The internal ITEST online community continues to be a private area accessible only to members, while a public website provides information about the program to all. Wenger et al. (2002) emphasize the importance of focusing on the private as well as the public community space, in order to encourage member involvement and gather information on key issues of importance to participants.

4. *Be Flexible*

Planning and coordination are important to developing, nurturing, and sustaining a community of practice. However, as noted above, it is also vital to remain open to trying new ways of communicating, listening to participant suggestions in order to improve offerings, and providing a wide range of offerings. The LRC has continually made adjustments throughout the life of the program. For example, a majority of community members indicated that they would rather participate in a one-hour conference call on a topic of interest (for example, participant recruitment and retention) followed by a brief summary publication than in a one-to two-week online dialog on the same topic.

5. *Offer Multiple Access Points and a Flexible Approach*

The LRC—in collaboration with community members—offers multiple access points and uses a flexible approach to encourage participation and engagement in the community. Examples of topics covered in yearly events follow:

- Approaches: Teaching GIS/GPS to students and teachers

- Content: Gaming and Simulation in Education
- Strategies: Participant Recruitment and Retention
- Dissemination: 2008 SITE Conference ITEST Symposium
- Working groups: Youth and STEM Skills Development
- Evaluation: Peer Exchange/Contribution to Evaluation Instrument Library

6. *Demonstrate Benefits of Participation to Members*

As outlined above, benefits to members include:

- Learning from each other
- Presentation and publication opportunities
- Partnerships to enhance project work
- Funding opportunities

Member leaders share their insights on benefits of community participation to potential new members in formal and informal ways, including at the yearly welcome to new projects webcast, annual face-to-face meetings, and individual interactions.

7. *Synthesize, Preserve, and Share Institutional Knowledge Within and Outside of the Community*

Through the private internal online community, the LRC provides community members access to archived annual meetings, webcasts, and electronic discussion list postings, *Round-Up* publications (summaries of key insights on a specific topic), informational and research briefs, and newsletters. These materials capture and preserve the lessons learned throughout the ITEST Program. A robust searchable database allows visitors to the LRC public website to learn about the program as a whole, access publications about the program work and learnings, and search for project information in a variety of ways, providing policymakers, practitioners, and researchers with access to information customized to their needs and interests.

The results of the participant evaluation surveys, interviews, and observations demonstrate that the LRC has successfully built a community of practice among ITEST projects. It has done so by employing a collaborative approach, encouraging leadership, being intentional in planning and coordination, providing infrastructure and multiple connection opportunities and methods, being flexible, offering multiple access points, demonstrating benefits to members of participation, and synthesizing, preserving, and sharing institutional knowledge within and outside of the community. The strategies, successes, and learnings of the LRC have important implications for all who seek to effectively create, support, and nurture communities of practice.

Implications and Questions for Future Work

In addition to supporting and disseminating the work of individual ITEST PIs, evaluators, and project staff, the ITEST COP helps support the program overall. The strategies outlined above contribute to ongoing program improvement and support the field of STEM education and workforce development in a number of ways:

- The PI Emeritus program invites PIs to continue their involvement in the ITEST COP after their award period has ended. In doing so, the program provides access to institutional knowledge of the program, promising practices, and archived data—stockpiling vital information to draw upon when opportunities arise to conduct follow-up studies.
- Small groups on topics such as computational thinking, informal learning, and scale-up help members of the community explore new issues, raise questions, and provide a test bed for new ideas—enabling an ability to rapidly respond to questions that emerge from policy, research and practice.

- Knowledge sharing facilitated through the COP generates products that the program disseminates widely both within and outside of the community through conference presentations, Web presence, and publications—building capacity around STEM education and workforce development topics.

Moving forward, we are challenged to explore the following questions to gain deeper insights into how the COP can continue to contribute to the ITEST Program as the program *and* its COP evolve and mature:

- What are additional factors that help sustain members' engagement in a COP over time?
- How can a COP continue to encourage and influence project PIs to engage in activities that reach beyond the obligations of their own projects and work for the betterment of the program community?
- In what ways does a COP promote the translation of research and lessons learned into practice by enabling rapid and effective dissemination of new knowledge from NSF into the national STEM education and workforce development communities?
- How can an active, thriving COP help ensure that a long-standing program continues to address current and emerging issues and problems?
- How does a COP add value to a program over time, thus helping sustain the program?

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