

Chapter 2

The FI³T Project

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Abstract This present chapter first describes the current STEM learning initiatives in the United States (U.S.) to address the challenge the nation is facing to develop a future workforce that is creative, innovative, and technology proficient. The chapter next introduces the Fostering Interest in Information Technology (FI³T) project, which emphasizes information technology (IT) integration and collaborative strategies in STEM learning. FI³T created a design community where high school students, high school STEM teachers, undergraduate/graduate student assistants, post-secondary STEM content experts, and partners from industry worked together in order for high school students to learn about, experience, and use IT within the context of STEM and explore related career and educational pathways. Following the project design strategies, the chapter describes project events and activities in detail. FI³T concentrated on all four areas of STEM, creating four project-based design teams to address IT use in science, engineering, technology, and mathematics. The project sponsored two cohort groups, each participating for two consecutive years with several year-round activities for students to gain IT enrichment experiences within the context of STEM, followed by alumni and follow-up activities. The chapter ends by reporting on the FI³T project research findings. Overall findings indicated that STEM learning experiences supported through technology enhanced, inquiry- and design-based collaborative learning strategies have significant impact on urban high school students' STEM learning and critical thinking skills. Some degree of impact on attitude changes toward STEM and career aspirations in these fields was also in evidence.

Keywords STEM • IT • Inquiry-based learning • Design-based learning • Urban education • High school education • Afterschool programs

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2.1 Introduction

In the United States (U.S.), from Congress to local school districts, a wide range of legislative offices and educational institutions continue to give even more emphasis on STEM learning, particularly in the last century. U.S. leaders and educators are well aware that they must meet the challenge to prepare current and future generations of the workforce for the complex demands of the economy and the evolving ways of living, learning, and working. In this undertaking, varying federal, state, and local initiatives support and fund in and out of school STEM learning experiences to help students and teachers build 21st century skills and knowledge needed to succeed in a science and technology-driven world.

As highlighted in multiple reports, the U.S. needs to develop a workforce that is creative, innovative, and technology proficient (Business Roundtable 2005; Committee on Prospering in the Global Economy of the 21st Century and Committee on Science Engineering and Public Policy 2007; Domestic Policy Council Office of Science and Technology Policy 2006). In addition, collaboration, critical thinking, problem-solving, teamwork, and leadership are part of this new skill set (Levy and Murnane 2005; Partnership for 21st Century Skills 2008).

Despite significant funding of IT and STEM youth programs over the last two decades, inequities in STEM education in the U.S. have been documented, disseminated, and met with national concern (see Congressional Commission on the Advancement of Women and Minorities in Science, Engineering and Technology Development 2000; Laorenza et al. 2012; National Center for Women and Information Technology NCWIT 2007 and 2009; National Research Council 2011; Office of Science and Technology Policy Executive Office of the President 2007; Sandler et al. 2012). As Laorenza et al. argue, “data consistently demonstrate that underrepresented students (e.g., African American, Hispanic, women and girls, students in poverty, and English language learners) are left behind the traditional White male students from the earliest STEM educational opportunities through the stage when students choose career paths.” In 2004, less than 9 % of computer science majors were African American, while only 4 % were Hispanic. For women, the lack of representation is even greater, with a 70 % decline of incoming female undergraduates pursuing computer science degrees in the U.S. between 2000 and 2005 (NCWIT 2007). The NCWIT (2009) also reports that women make up only 25 % of the IT workforce. Women’s representation also varies by race/ethnicity; 18 % white, 4 % Asian, 2 % African American, and 1.5 % Hispanic. Laorenza et al. further argue that “despite the attention the inequities in STEM have endured overtime....STEM jobs continue to be a viable career path; however, with persistent inequalities, these opportunities are not opportunities for all students.”

The National Research Council (2011) highlights the importance of providing opportunities for students from underrepresented groups because of “changing immigration patterns, the rapid improvement of education and economies in developing countries, and a heavy focus on talent development” (p. 4). Efforts in K-12 to serve the underrepresented and underserved groups and studying their

STEM career trajectories play a major role in addressing these crucial issues. In this undertaking, the National Governors Association and Council for Competitiveness (2007) highlights that one of the necessary steps is to develop a “brain-force” through K-12 student-centered research projects, which focus on inquiry-based, real-world project-based IT/STEM (Information Technology in Science, Technology, Engineering, and Mathematics) initiatives with a strong emphasis on innovative 21st century career and educational pathways. The National Science Board (NSB 2010) echoes the earlier highlights and further recommends that in STEM areas, students should have the opportunity to experience peer collaboration and interactions with practicing scientists, engineers, and other experts. Other reports point out that the global competitive demands facing the nation as a whole can only be met by diversifying the current/future IT workforce while also encouraging underrepresented and underserved populations to pursue careers in IT- and STEM-intensive fields (Congressional Commission on the Advancement of Women and Minorities in Science, Engineering and Technology Development 2000; National Research Council 2011; Office of Science and Technology Policy Executive Office of the President 2007).

In response to the national call to address the growing demand for a STEM workforce, the National Science Foundation (NSF) established the Innovative Technology Experiences for Students and Teachers (ITEST) program in 2003. Focusing on engaging students, teachers, and other educators in authentic, technology-based STEM activities through formal and informal science learning, ITEST aimed at discovering and disseminating best practices for developing the next generation of STEM workforce (National Science Foundation 2007). Since its launch, the ITEST program has supported over 250 projects, representing various regions of the nation as well as urban, rural and suburban settings (Education Development Center 2015).

In the earlier years, the ITEST program supported three types of projects: “youth-based,” “research,” and “scale-up” (National Science Foundation 2007). Youth-based projects worked with students in formal and informal settings involving institutions like K-16 schools, museums, and community based organizations to implement innovative STEM learning activities. Research projects worked with these communities to help answer challenging questions related to student engagement, motivation, persistence, and career intentions. Scale-up projects focused on identifying how to replicate promising STEM learning experiences for students and teachers on a larger scale. Later in the process, ITEST re-defined the type of projects to support, naming them “Strategies” and “SPrEaD” (Successful Project Expansion and Dissemination). Strategies projects focus on the creation and implementation of innovative technology-related interventions. SPrEaD projects support the wider and broader dissemination and examination of innovative interventions (National Science Foundation 2013).

In general, ITEST projects provide a unique opportunity to bring together varying educators from schools, universities, and local organizations. Most of these projects provide an opportunity for teachers and students to use technology in real-world settings. They involve advanced STEM content from areas such as

Bioscience, Computer Science, Engineering, Environmental Science, and Mathematics (Education Development Center 2015). Projects offer after school, Saturday, and summer programs to boost interest, engagement, and achievement in IT and STEM learning. In these programs, role models demonstrate skills and mentor young students. Students construct robots, rockets, video games, molecular models, and more, all to learn the science and mathematics of what interests them.

2.2 Purpose of the Chapter

This present chapter reports on a specific ITEST “strategies” project, Fostering Interest in Information Technology (FI³T). Focusing on all four areas of STEM, the FI³T project emphasizes information technology (IT) integration and collaborative strategies to increase opportunities for underrepresented and underserved high school students, particularly those from disadvantaged urban communities, in order for them to learn, experience, and more importantly use IT within the context of STEM. Addressing the critical framework undertaken in the FI³T project, describing the project design and implementation activities, and reporting the key findings from the FI³T project research, the chapter aims at (a) assisting and guiding educators who are interested in offering similar STEM learning projects; (b) informing school-level decision makers and funding agencies about research-based best practices in STEM programming; and (c) supporting higher education faculty thinking about developing further grant and research proposals for K-16 collaborations.

2.3 The FI³T Project

The FI³T project was designed to increase the opportunities for underrepresented and underserved high school students, particularly those from disadvantaged urban communities in Southeastern Michigan to learn, experience, and more importantly use IT within the context of STEM. The project called for the investment and robust participation of postsecondary colleges and schools, area school districts, and the business, industry, and government sectors. The “Community of Designers” approach introduced by Mishra et al. (2006) provided the framework for the collaborative partnership among a range of participants involved in the program.

2.3.1 Critical Framework

As Mishra et al. (2006) describe, the Community of Designers is an environment in which groups of individuals work collaboratively to design and develop solutions to

authentic problems. The authors highlight the essence of this approach with four key words: *community*, *design*, *products/solution*, and *authentic problems*.

Mishra et al. (2006) describe “community” as the social arrangement of the approach. The authors explain that a purposefully constructed community should include individuals with a variety of expertise and expectations, allowing members to contribute to and benefit from community engagement. Referencing earlier studies (Cole 1996; Vygotsky 1978), Mishra et al. highlight that within the context of social constructivism, design projects provide an environment for sustained inquiry and collective creativity.

Mishra et al. (2006) explain that “design” specifies the activity dimension of the approach. The authors argue that building upon ideas grounded in situated cognition theory (Brown et al. 1989), learning is contextualized in the process of doing-solving an authentic problem of practice. Design-based activities provide the rich context for learning, sustained inquiry, and revision, and are well suited to develop the deep understanding needed to apply knowledge in the complex real-world domains. The authors point out that emphasis on design is informed by research on the use of design for learning complex and interrelated ideas with many theoretical and pragmatic connections to project-based learning.

Mishra et al. (2006) argue that while “products/solution” stresses the goal-oriented psychological dimension, “authentic problems” addresses the motivational challenge, which becomes the driving force behind the work of the community. Authentic problems that project participants face and need to work on provide the connection between what they learn and what they actually do. Citing other research in this area (e.g., Barab and Duffy 2000), the authors point out that design team participants deal with authentic and engaging ill-structured problems that reflect the complexity of the real world. The authors highlight that learners have to actively engage in practices of design, inquiry, and research in collaborative groups to design tangible, meaningful artifacts as end products of the learning process. The authors further describe that the actual process-by-design is the anchor around which learning happens. This evolving artifact is also the test of the viability of individual and collective understandings as participants test their and others’ conceptions and ideas of the project.

Mishra et al. (2006) point out that implementing a community of designers breaks down into four stages that each design team experiences over its lifecycle: identifying participants and problems, forming communities, providing leadership and support, and working on authentic problems. The authors argue that identifying potential participants is the key to the success of the community of designers approach. Normally, an open call for participation with description of the program and inviting interested members is critical in identifying the design community members. Mishra et al. point out that forming communities with experts and interested individuals constitutes another important component of implementing the community of designers approach. Depending on the situation, the potential audience of the design community should include varying stakeholders. One member of the design community is often needed to provide overall leadership and serve as a resource to all the design community members at any given time. Other general

support should also be available often to serve as consultants to design communities. Once the design community is formed, members of the community begin to work on identifying authentic problems and exploring solutions to the problems over a period of time, during which they may encounter the boundaries and intersections of their expertise and interest.

One would argue that in many ways implementing a community of designers framework parallels with the principals of the “community of practice” idea where Lave and Wenger (1991) describe learning through social engagement in which members share understandings regarding what they are conducting and what that means in their daily life and for their community (cited in Parker et al. 2010). Further referencing Lave and Wenger, the authors highlight that “these communities foster mutual engagement among the members, while they work on a joint enterprise using shared repertoires of terminology and skills” (p. 190).

Consistent with the aforementioned discussions, the FI³T project created a design community where high school students, high school STEM teachers, undergraduate/graduate student assistants (U/GSAs), post-secondary STEM content experts, and partners from industry worked together in order for students to learn about, experience, and use IT within the context of STEM and explore related career and educational pathways.

The FI³T project’s design community consists of three interrelated components: (a) students’ IT/STEM learning experiences; (b) project-based design teams; and (c) distributed on-demand resources and support. Figure 2.1 illustrates the model’s conceptual basis, showing that the IT-rich learning experiences within the context of STEM are at the core of the project. The figure also depicts the more specific roles of key participants, with high-school students, assisted by a support layer comprised of K-12 STEM teachers, STEM content experts, and U/GSAs, coming from partnering institutions and local industries.

2.3.2 IT/STEM Concentration

The FI³T project concentrated on all four areas of STEM, creating four project-based design teams to address IT use in science, engineering, technology, and mathematics. The following section describes the particular applications in each IT/STEM area:

IT/Science applications included measurement, modeling, and mapping—making location measurements using GPS and integrating the measurements in a GIS system, using temperature and light sensors in the sciences, and creating mathematically based models using the ISEE Systems’ computer application STELLA.

IT/Technology applications included technological tools and languages for designing and developing Web applications such as Web-based games and chat rooms, allowing students to gain experiences with the basics of visual programming, familiarizing themselves with integrated development environments such as Visual Studio and/or Alice, and practicing designing and developing games.

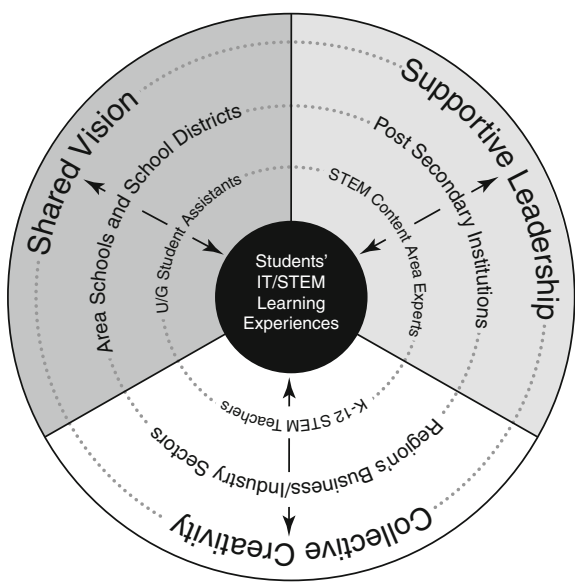


Fig. 2.1 Structure of FI³T communities of designers

IT/Engineering applications included the basics of robotics and its applications such as modeling robots, programming robots, and integrating robots into an application environment for example an industrial manufacturing system or a medical application in a surgery operating room.

IT/Mathematics applications included focusing on statistical science with consideration of the two-sample comparison problem, the simple regression/correlation problem, and the simple analysis of covariance problems taking examples and assignments from public health science, environmental science, and/or manufacturing reliability using Minitab, Fathom, and Excel software.

2.3.3 Partnership

The FI³T project approaches the IT/STEM-learning issue as a community-wide responsibility. Therefore, the project called for the investment and robust participation of higher education institutions, K-12 schools, and business, industry, and government sectors as well as parents and volunteers.

Aligned with this notion, participating partners of the FI³T project included (a) University of Michigan-Dearborn's College of Engineering and Computer Science, the College of Arts, Sciences, and Letters, and the School of Education; (b) Detroit Public Schools; (c) the Survivability Technology Area of the US Army's Tank Automotive Research Development and Engineering Center (TARDEC), Dassault Systemes'/DELMIA Corporation, Reactor Zero (a local game developer company), FANUC Robotics, Inc., the Society of Manufacturing Engineers (SME), SIEMENS, the Barbara Ann KARMANOS Cancer Institute, the Systems Analytics and Environmental Science Department at Ford Motor Company, the Advanced and Manufacturing Engineering Quality Department at Ford Motor Company, and The 21st Century Digital Learning Environments; and (d) parents and volunteers. These partnerships provided project participants with opportunities and support to work directly with IT and STEM professionals and observe examples of real-world workplace applications.

The university involved in the FI³T project, the University of Michigan-Dearborn (UM-Dearborn), is a regional university within the University of Michigan system. UM-Dearborn is located in the city of Dearborn, part of the Detroit Metropolitan area and the epicenter of the largest concentration of advanced automotive manufacturing research and development headquarters in the world. UM-Dearborn offers undergraduate, graduate, and professional degrees in the liberal arts and sciences, engineering, management, and education. Most of the programs offered involve information technology components in the context of science, technology, engineering, and mathematics. The university has long maintained links with the region's K-12 schools, and a great number of these ties are to the area's disadvantaged schools. UM-Dearborn is also well known for its close collaborative partnerships with the region's business, industry, and government sectors as evidenced by the university's existing relationships with the "big three" automotive companies, their vendors and suppliers in Southeastern Michigan.

The school district involved in the FI³T project, Detroit Public Schools, is a major urban school district located in Southeastern Michigan. It is the largest school district in the state serving nearly 66,000 students (mostly African American) throughout a major city area (Dawsey 2011). The district has a long history of challenging issues including shrinking population of students, financial instability, school closings, and a low high school graduation rate. When the FI³T project was launched in 2008, it was reported that the high school graduation rate was 24.9 % in the district, the worst in the nation among the largest school districts that year (Mrozowski 2008).

Southeast Michigan businesses that make significant use of IT have supported the project in various ways. Participating faculty also connected with their own organization and business contacts outside Michigan to obtain software and other materials to support the program. Local businesses advised IT/STEM design teams on project activities; provided educational and other materials; hosted field trips to their sites during summer camp; and their representatives served as role models for IT careers.

Business partners of the project included a total of nine business, industry, and government institutions in IT/STEM fields.

The FI³T project considered parental and volunteer involvement as a critical factor for the project's success and continued student engagement and retention. Parental involvement was fostered through scheduled seminars and outreach opportunities in order to promote their investment and robust participation in the project's events and activities. Volunteers from the university's students and staff, community members from participating schools, industry, and government sectors, and students' family members were invited to strengthen the project's support structure.

2.3.4 Participants

The FI³T project began in fall 2007 and completed its startup/planning phase in June 2008. Major project activities started at the beginning of July 2008. The three years of the major project implementation were completed at the end of August 2011. During the implementation phase, the FI³T project included two cohort groups, each participating in two consecutive years of project activities with an overlap in the second year so that all participants receive two years of enrichment activities. The project received a one-year no-cost time extension to conduct follow up research with project graduates and their parents throughout the 2011–2012 school year. The FI³T project activities ended on August 31, 2012.

Focusing on four project-based design teams (IT/Science, IT/Technology, IT/Engineering, IT/Mathematics) in each cohort, the FI³T project targeted to include 10 high school students, one STEM area high school teacher from the participating school district, one U/GSA and one postsecondary STEM content expert from participating higher education colleges and schools in each design team. Each design team, therefore, targeted 13 collaborating members. STEM teachers team taught and shared the planning and instruction of all project activities with postsecondary STEM content faculty. Each design team included the participation of a U/GSA as an important member of the support structure. One specialized member of the project leadership team (in STEM areas) led each design team. Each design team leader identified a collaborating business, industry, government, or university sector in their particular area of interest. These partnerships provided project participants with opportunities and support to work directly with IT and STEM professionals and to see examples of real-world workplace applications.

2.3.4.1 High School Students

Within two cohorts, the FI³T project included a total of 77 10th–12th grade high school students. Students joined the project at the beginning of their 10th grade and

completed the two-year-long project activities at the end of their 11th grade, followed by alumni and follow-up activities during their senior year as future college students.

Coming from four comprehensive high schools of the partnering school district, participating students were selected from targeted underrepresented and underserved populations through a multidimensional screening process. The first step of the recruitment effort involved a “Support Your Child’s Career” event offered at the participating University of Michigan-Dearborn campus for potential project participants’ parents. The second step required self, teacher, and parent nominations, along with students’ autobiographical statements indicating their interest and current academic success in science and mathematics. Student and parent signatures confirming their commitment to the project activities were also required.

The FI³T project targeted a 100 % retention rate for participating students through the combination of academic and financial support systems. The project regularly emphasized the “goal oriented” nature of the program rather than a “degree/certificate” which is considered one of the working strategies for student retention (Habley 2005). Habley also indicates that student retention is “high” when program activities highlight a competition. With their projects designed during the FI³T program, students were encouraged, advised, and supported to participate in pre-college competitions such as the Annual Science and Engineering Fair of Metro Detroit. Students were provided an annual cash stipend based on their attendance records. The social environment surrounding students with supporting parents, teachers, content experts, project leaders, and community members was also utilized to impact student retention.

2.3.4.2 K-12 STEM Teachers

Participating teachers were selected from STEM area-related certified high school teachers of participating high schools with a minimum of 5 years of teaching experience based on the nominations and recommendations from district curriculum supervisors.

Fifteen teachers were recruited to participate in an initial two-week intensive university course focused on the four STEM content areas and strategies for using technology. Based on their progress in the course, five teachers were selected to continue in the program as core teachers and partners in the four design communities—one each in science, technology, and mathematics, and two (as co-leaders) for engineering STEM areas. Academic and financial incentives provided for participating school teachers centered the retention strategies for this group of participants.

Although the original plan called for recruiting a second set of 15 teachers and identifying another group of core teachers to participate in the project during the second cohort, problems in the partnering school districts prevented recruitment and training of a second cadre of teachers. Thus, the original 5 core teachers continued in the program until the end. However, by the final year of the program, only 4 of

the original 5 core teachers continued to participate. Changes in school assignments and layoffs affected their participation in the program. One lost earlier in the project returned during the final extension year.

2.3.4.3 Undergraduate/Graduate Student Assistants

Each design team called for the participation of a U/GSA as an important member of the support structure. Each year four U/GSAs (one from each STEM area) provided technical support to the project participants. They assisted the project leadership in disseminating the project's results. The U/GSAs were selected from UM-Dearborn's participating schools and colleges based on their STEM discipline. The selection criteria included an outstanding GPA with excellent communication and teaching skills. Academic and financial incentives centered the retention strategies.

2.3.4.4 Post-secondary STEM Content Experts

Participating STEM content faculty were selected from the schools and colleges of the participating higher education institution. The project leadership team identified faculty members whose interest, teaching, and research were in STEM areas and invited them to participate in the project.

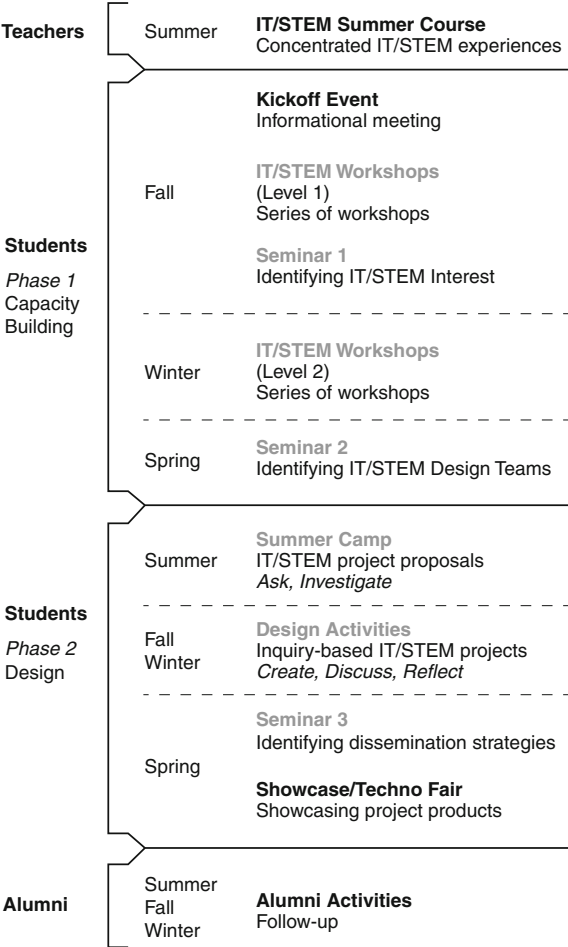
Although there were some changes in faculty members involved in programming over the course of the project, many remained active for the entire project. They played a major role in organizing and implementing student workshops, working directly with students during workshops and on long-term investigations, and assisting students in preparing presentations of their projects. Academic incentives and course releases for faculty members centered the retention strategies. Research and publication opportunities for participating faculty were also encouraged and facilitated as part of the incentive and retention strategies.

2.3.5 Project Events and Activities

The FI³T project sponsored two cohort groups, each participating for two consecutive years, followed by alumni and follow-up activities. The project started with an initial IT/STEM summer course to recruit participating teachers, followed by several year-round activities for students to create IT enrichment experiences within the context of STEM and explore related 21st century education and career pathways. The project also distributed online learning activities using the project's website (<http://fit.umd.umich.edu>), blog, and podcasting sites, and thus aimed at establishing a culture of collaboration and discourse that extends participation outside the confines of the formal scheduled events.

For each student cohort, the work of FI³T was accomplished through summer and school-year activities within two different but interrelated phases. Phase 1 (Capacity Building), the first nine months of the program, was primarily a time for exploration and capacity building among students to increase their knowledge, skills, and interest in IT/STEM-related fields. Phase 2 (Design) focused on facilitating student activities in which they engaged in designing inquiry-based authentic projects of science fair quality using what was learned in the capacity-building phase of the program. Through several alumni and follow-up activities, the project enabled continued communication, networking, and collaboration among project participants after they completed the project’s planned activities. These activities were centered around advising project graduates to participate in nationwide competitions with their projects. They also received assistance in taking pre-college classes related to IT and STEM areas during their senior year of high school and guidance with their college applications. Figure 2.2 below illustrates the project

Fig. 2.2 FI³T project event and activities



events and activities in a single cohort, followed by the description of the major events and activities in each phase. The general scopes of events and activities are summarized in Table 2.1.

2.3.5.1 IT/STEM Summer Course

The IT/STEM summer course was an initial activity designed to recruit the FI³T project's participating teachers. This one-semester three credit-hour graduate level course was organized around the four STEM fields to provide high school STEM teachers with concentrated IT/STEM experiences in order to build their knowledge and skills to learn various IT/STEM technologies, both hardware and software, and how to help their students learn to use them.

Four different STEM area faculty teaming with four STEM subject-area experts serving on the project management team taught the course together over two weeks in summer term where each team had 12 contact hours with teacher participants. The course content was aligned with the planned IT/STEM enrichment experiences for the project's participating students. The *science* part of the course concentrated on three different but related applications of IT in the sciences; measurement, modeling, and mapping. The *technology* section focused on technological tools and languages for designing and developing Web applications such as Web-based games and chat-rooms. The *engineering* component emphasized the basics of robotics and its applications as related to IT, including modeling robots, programming robots, and integrating robots into an application environment such as a manufacturing system or a medical application. The *mathematics* section focused on statistical science with consideration of the two-sample comparison problem, the simple regression/correlation problem, and the simple analysis of covariance problem taking examples and assignments from public health science, environmental science, and manufacturing reliability.

In addition to its instructional objectives, the course allowed FI³T project leadership to observe participating teachers' performances during the course and select one core teacher for each STEM area for the project's continuing year-round enrichment experiences for students. At the end of the summer course, the project management team conducted a rigorous review of the attending teachers and identified five "core" teachers—one each in science, technology, and mathematics, and two (as co-leaders) for engineering areas. Coming from four different high schools, these five core teachers became part of the project management team, participating in project planning and decision-making and helping facilitate school-year student IT/STEM workshops and project activities.

2.3.5.2 Phase 1 (Capacity Building)

Phase 1 started with the preparation activity (IT/STEM summer course described above) for K-12 STEM teachers, followed by a kickoff meeting as the school year

Table 2.1 General scopes of major project EVENTS and activities

Design teams	Project activities			
	Level 1 workshops	Level 2 workshops	Summer externships	IT/STEM projects
Science	-Exploring the use of a light sensor connected to a computer -Introduction to GPS receivers and mapping	-Using sensors to make measurements important in the environmental sciences -Exploring motion of battery-powered cars, fan carts, and dropped or tossed balls -Using computer language VPython -Using GPS and GIS	-Observing ways that modeling, measuring, and mapping are used in working laboratories -Site visits to US Army Tank Command, Warren, MI, and the Michigan Department of Natural Resources	-Using sensors in the environmental sciences -Mathematical models that relate measured quantities -Use VPython to view, in three dimensions, motion described by the models they developed -Mapping into the neighborhood, mathematical descriptions of directions
Technology	-Using Visual Studio to design and develop the three tiers of a Web application for a simple business-to-customer application	-Using advanced Visual Studio concepts; graphical user interface, graphics and multimedia, databases and ADO.NET, ASP.NET, Web forms and Web Controls	-Observing the work of Web application developers in Dassault Systèmes’/ DELMIA Corporation	Designing Web-based games (e.g., jeopardy) and chat-rooms
Engineering	-Introduction to the basic of robotics, and overview of robotics simulation software packages	-Building a robot model using the solid modeling software packages, ROBCAD - demonstration of robot operation in a manufacturing environment and programming benchtop and mobile robots	-Observing robots operations in an application environment. Field trips to FANUC Robotics, Inc -Working with UM-Dearborn students enrolled in Industrial	-Hands-on experience on modeling robots, programming robot, and integration of robots in an application environment such as manufacturing system

(continued)

Table 2.1 (continued)

Design teams	Project activities			
	Level 1 workshops	Level 2 workshops	Summer externships	IT/STEM projects
			Robots class labs -Demonstration of CIM system in the manufacturing engineering labs and mobile robots design and build by the Intelligent Systems Club	-Hands-on experiences in the Robotics lab at UM-Dearborn for creation of the projects
Mathematics	-Using Minitab (a statistics package) to create displays and tables. Students investigate two to four biological, environmental or biomedical datasets involving comparison	-Using Minitab to create scatter plots for bivariate measurement data together with simple linear regression lines and covariance analysis	-Illustrate what working statisticians do and how statistical science is intertwined with science -Field trips to Systems Analytics and Environmental Science Department and Advanced and Manufacturing Engineering Quality Department at Ford Motor Company	-Planning a study, data collection over a period of time, analyzing the data, drawing conclusions, and writing a report. Projects to involve environmental science, working with on campus scientists who have an on-going environmental study of the Rouge River watershed or working with the on-campus Environmental Interpretive Center

began for participating sophomores (10th grade), a set of IT intensive STEM area workshops for students during the year, and seminar meetings near the end of the fall and winter semesters. Capacity-Building activities took place on the campus of the participating university. The Phase 1 concluded with real-world field-based experiences during the following summer with opportunities for students to work directly

with IT and STEM professionals and see examples of real-world workplace applications. The total number of instructional hours per student during this phase was 54.

2.3.5.2.1 Kickoff Meeting

This whole-group orientation meeting was designed to motivate participants by informing them that their work within the project was part of a larger national initiative. Second, the meeting was utilized to explain the roles and responsibilities of all engaged members in detail. Community members from collaborating schools, institutions, and organizations, and parents and volunteers attended the meeting.

2.3.5.2.2 Level 1 Workshops

During the fall semester, each STEM area offered two three-hour content-specific Level 1 workshops to all participating students. These workshops consisted of brief presentations followed by hands-on activities to provide students the opportunity to learn about IT toolsets within the context of STEM. A second purpose of the Level 1 workshops was to allow participating students to identify specific areas of interest within IT/STEM fields. During this period, STEM area teachers, faculty members, and the project leadership team observed and surveyed students for their interest in specific STEM subject areas and assisted them to narrow down their interest into two specific STEM-related fields.

2.3.5.2.3 Seminar Meeting

A whole-group seminar meeting was held near the end of the fall semester. At the meeting, students, teachers, content experts, project leaders, and parents collectively focused on finalizing decisions for two specific areas of interest in STEM fields and planned the upcoming activities during the following winter semester.

2.3.5.2.4 Level 2 Workshops

During the winter semester, a set of small-group in-depth Level 2 IT/STEM workshops were offered to the students in their identified two STEM areas of interest. Each STEM area offered four three-hour content-specific IT/STEM workshops, allowing each student to participate in a total of eight workshops related to their identified two STEM areas. Throughout these workshops, participating students had the opportunity to learn advanced use of IT toolsets within specific STEM areas. Level 2 workshops also allowed students to narrow down their interest into one specific STEM area and help them to join in one specific IT/STEM design team.

2.3.5.2.5 Seminar Meeting 2

Similar to Seminar Meeting 1, a whole-group seminar meeting was conducted in late spring of the academic year to form four design teams (one for each IT/STEM area) based on the interest of participating students. The meeting was also used to plan for externship activities involving real-world field-based experiences during the following summer.

2.3.5.3 Phase 2 (Design)

The Design phase started with a summer externship followed by a series of site-based sessions for each individual design team and a whole-group seminar meeting near the end of the following school year. The Design year ended with a techno/career fair.

During this phase of the project, participating STEM teachers continued to collaborate with higher-education faculty, undergraduate/graduate students, and business partners to facilitate IT-supported STEM project activities for high school students assigned to their IT/STEM design team. The overarching task of each design team in this year was to develop inquiry-based authentic projects that were of at least science fair quality using one or more content-specific IT tools explored during the previous Capacity Building year and stimulating ideas/experiences gained during the summer camp. The Design phase ended with a techno/career fair meeting during the following spring term. During this phase, students were expected to spend approximately four hours in each week on their projects during the anticipated 30 weeks of the school year, bringing the estimated total number of contact hours to 150.

2.3.5.3.1 Summer Externship

The summer externship consisted of field-based experiences and preparation for design activities. At the two-week summer program (1 week in mid-June and another one in late August), project participants met and observed the work of scientists and professionals in IT/STEM fields. Collaborating business, industry, government, and university sectors hosted these sessions. The project facilitated eight different day-long field trips (two for each STEM design team) each emphasizing IT-related career and educational pathways within the context of STEM, and including debriefing activities after each one. The summer program was also aimed at readying the students for the project development stage that occurred during the subsequent collaborating school year.

2.3.5.3.2 Site-Based Sessions

Aligned with the cyclic inquiry model's five major steps (Bruce 2003)—Ask, Investigate, Create, Discuss, and Reflect (Fig. 2.3), the design year involved five segments, each including multiple site-based sessions. As part of the summer program discussed above, the project facilitated collaborative learning experiences where students learned how to design and conduct inquiry-based authentic projects, more specifically learned how to Ask, how to Investigate, how to Create, how to Discuss, and how to Reflect. These theoretical discussions then were linked to students' authentic projects to provide practical applications. The focuses and approaches of design steps were as follows.

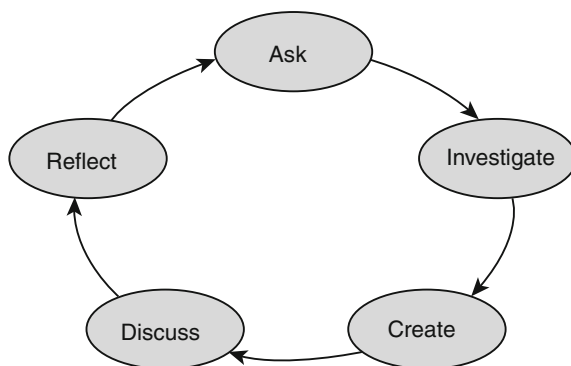
2.3.5.3.2.1 Step 1 (*Ask*)

Step 1 took place during the summer program. Led by one specialized member of the project leadership team, each STEM area held a series of meetings to discuss IT-intensive authentic project ideas aligned with appropriate federal and state standards within the focus area of each design team. At this stage, each student began to focus on a question or problem, defining and describing it. Students were assisted in the process by the design team members. During this process, the design team leadership closely surveyed the focus and interest of each participating student to facilitate individual and/or small-group projects. Even though initial questions were redefined throughout the learning process, they naturally lead to the next stage in the process: investigation.

2.3.5.3.2.2 Step 2 (*Investigate*)

Step 2 also took place during the summer program and was conducted in a similar manner as Step 1. Students began to collect information about their questions. This process included research using reading, observing, interviewing, or doing

Fig. 2.3 Five major steps of the cyclic inquiry model (Reproduced from Bruce 2003)



exploratory experiments. Even though the design team leadership assisted students in the investigations, it was important that students had ownership in the process.

Starting with the new academic year following the summer program, students engaged in the following three stages of their project design (Create, Discuss, and Reflect) iteratively. Students were expected to spend an average of four hours weekly on their projects until the early spring of the year. Each design team facilitated ongoing meetings and discussions during this process using the scheduled meetings and project's social networking sites. Design team interaction was facilitated on an ongoing basis to assess project progress.

2.3.5.3.2.3 *Step 3 (Create)*

As students made numerous connections between the results of their investigations during this stage, they began the creative task of going beyond their previous experiences to create new ideas of how to answer their questions or solve their problems. Again, the design team members assisted the students during this process.

2.3.5.3.2.4 *Step 4 (Discuss)*

Students shared their investigations and new ideas with others. By comparing notes and discussing their results, they built a design community which increased the relevance of their projects.

2.3.5.3.2.5 *Step 5 (Reflect)*

Reflection consisted of taking the time to look back at the question, the inquiry research path, and the conclusions made. During this process, students decided whether a solution had been found and saw what further questions had emerged. Thus, the circle of inquiry began anew.

The general scope of FI³T project activities and events described above are summarized in Table 2.1.

2.3.5.3.3 Seminar Meeting 3

A three-hour whole-group seminar meeting took place near the end of the school year where design teams rejoined to share their experiences related to the design activities. Project participants discussed strategies for disseminating their projects to peers across their district and throughout the region. The meeting also provided time for students to work on their project presentations at the following techno/career fair.

2.3.5.3.4 Techno/Career Fair

At this half-day-long exposition, participants showcased their projects and discussed their experiences with the community. The fair also served participating colleges and schools and the region's business, industry, government, and university sectors to promote admission and career services related to IT and STEM fields. Community members from collaborating institutions and parents were invited to the fair.

2.3.5.4 Alumni and Follow-up Activities

Through several alumni and follow-up activities, the project enabled continued communication, networking, and collaboration among project participants after they completed the project's planned activities. The FI³T graduates were advised and assisted with participating in nationwide competitions with their projects. The project faculty and teachers provided assistance to students who wish to take pre-college classes related to IT and STEM areas during their senior year of high school. Students also received continued guidance with their college applications. Students from the first cohort were invited to mentor students in the second cohort with their design projects. The FI³T project administered an alumni meeting at the end of the three-year project inviting all first and second cohort project participants, parents, and partnering university, business, industry, and government sectors to discuss the influence of the project on the students' education and career. This allowed the project leadership to survey how the project impacted the students' ability to acquire knowledge and their choice of career while they were in high school and achievement in IT and STEM related courses while they were in college.

2.4 Key Findings from the FI³T Research

The FI³T leadership investigated the impact of the project on participating students' (a) IT/STEM technology skills, (b) frequency of IT/STEM technology use, (c) understanding of IT usage in STEM-oriented fields, (d) attitude changes toward IT/STEM, (e) desire for a career in IT/STEM-oriented fields, and (f) critical thinking skills. Findings from the FI³T research have been presented in two recent articles (see Duran and Sendag 2012; Duran et al. 2014). The following section provides a summary of the FI³T research key findings under three themes; IT/STEM learning, career intentions, and critical thinking.

2.4.1 IT/STEM Learning

Duran et al. (2014) reports that the FI³T project experiences significantly impacted urban high school students' common technology skills such as using computers, Internet, productivity tools, and Web 2.0 tools. The authors further report that participating in the project resulted in significant impact on students' IT/STEM technology skills such as GPS, GIS, and robotics programming. In general, the experiences in the project also improved participating students' frequency of common and advanced IT/STEM technology use. Two specific areas of impact regarding frequency of use included science- and engineering-related IT/STEM toolsets.

Another significant positive change was observed in the area of students' understanding of what IT is and how STEM scientists and experts use IT in their workplaces (Duran et al. 2014). For instance, the authors report, at the end of the program, students showed better understanding of how scientists, engineers, or mathematicians use IT as they learn about and develop new concepts.

Another area that Duran et al. (2014) studied was related to the FI³T project's impact on students' attitudes toward IT/STEM. As the authors report, outcome in this particular area indicated mixed results. It appears that the project experiences increased awareness of mathematics and technology and student interest in these two areas. At the end of the program, the authors indicate, participating students seem to realize that science is more than memorizing facts and procedures. The study reports that students also appeared to better realize that mathematics is useful in their lives outside of school. Duran et al. reports that their study findings in the area of attitude changes with mixed results might be related to a positive attitude that students brought to the FI³T project. The authors argue that given the fact that participating students volunteered to join the project, initial high interest and positive attitude are understandable and leave little room for change.

2.4.2 Career Intentions

FI³T research findings related to the impact of the project on students' intention for a career in an IT/STEM-oriented field indicate a mild agreement among student participants (Duran et al. 2014). In general, the findings highlight that students indicated limited desire for a career in mathematics or science areas, but fairly strong aspiration for a career that uses a lot of technology. More than half of the study participants (55 %) indicated increased or sustained interest in IT/STEM-oriented fields; over 13 % indicated decreased interest in such a future profession; and the remaining 32 % reported that they did not change their interest in non-IT/STEM careers from beginning to the end of the project.

Duran et al. (2014) points out that impacting over 55 % of study participants' career aspirations could be argued as a considerable effect of the FI³T project

experiences. However, the authors argue, one should also explain why such an extensive two years of programing with varying resources and support structure did not influence the other half of the participants' career intentions toward an IT/STEM field. In their study, Duran et al. discusses the possibility that perhaps the learning experiences provided within the FI³T program were not sufficient enough to significantly impact high school students' career aspirations, requiring additional interventions. Or, the authors argue, it might be the case that there are other external factors that impact high school students' career choices. Highlighting current literature (Scott 2012; Pollock 2004), the authors point out some dynamics why high school students are not attracted to STEM fields, such as misconceptions about working styles of people successful in the field, lack of access to desirable role models, lack of interest in the field among their peers, and lack of confidence in the abilities perceived necessary for success in IT and STEM fields. The overall findings from the FI³T research confirm the current literature and suggest that further research is necessary to better understand the impact of afterschool STEM programs on high school students' career aspirations.

2.4.3 *Critical Thinking*

Duran and Sendag (2012) investigated the development of critical thinking of urban high school students who participated in the FI³T project during the second cohort. The study highlights possible impact of IT/STEM experiences on critical thinking development through technology-enhanced, inquiry and design-based collaborative learning strategies implemented in the FI³T project.

Duran and Sendag (2012) report that the first objective of their study was to investigate the initial critical thinking skills (CTS) profiles of the study participants who were coming from a major urban school setting. The majority of the participants (83 %) were African American and most of them were female (64 %). Most of the students were at sophomore or junior level at the beginning of their participation in the study.

Duran and Sendag (2012) point out that compared to aggregated national data collected by Insight Assessment (Insight Assessment 2010a, b), the FI³T participants joined the program with relatively lower overall CTS test results (mean = 15.77), scoring between the 16th and 19th percentiles on the pre Test of Everyday Reasoning (TER) test. The TER test is a member of the California Critical Thinking Skills Test (CCTST) Family of Critical Thinking Skills Tests offered by Insight Assessment (Insight Assessment 2015).

The second objective of the Duran and Sendag (2012) study was to investigate if there were any differences in the CTS profiles of the participants who completed the FI³T project and who did not. Findings indicated that the difference between these two groups was not statistically significant. In other words, the CTS profiles of study participants who completed the FI³T project and who did not were similar at the beginning of their participation in the project.

The third and main objective of the Duran and Sendag (2012) study was to investigate if there was any significant increase in the CTS of the FI³T project participants throughout their participation. Findings indicate that study participants who completed the project experiences significantly improved their CTS throughout their participation in the project. In addition, post-program CTS scores of the participants were more homogeneous than pre-program CTS scores. Duran and Sendag argue the possibility that the IT/STEM experiences gained through the FI³T project significantly impacted program completers' critical thinking skills. The authors also point out that their study was a pre-test/post-test design and without an experimental study with a control group, the study findings should be considered as preliminary.

2.5 Conclusion

The FI³T project design provides a unique collaborative environment for high school students in which they work with a group of experts from K-12, university, and industry to design and develop solutions to authentic problems. Another main feature of the program is its emphasis on IT knowledge and skills within the context of STEM-related fields. In addition, over an extended period of time, the project provides participants access to year-round enrichment experiences through technology-enhanced, hands-on, inquiry- and design-based activities around authentic projects with a strong emphasis on non-traditional approaches to learning and understanding.

Overall findings from the FI³T project indicate that STEM learning experiences supported through technology enhanced, inquiry- and design-based collaborative learning strategies have significant impact on urban high school students' STEM learning and critical thinking skills. Some degree of impact on attitude changes toward STEM and career aspirations in these fields was also in evidence. As the findings of FI³T research suggest and other studies reveal, when low-income urban students are exposed to well-designed inquiry-based materials that draw upon IT skills in sophisticated ways, youth not only learn science better, they become IT-fluent (Edelson 2001; Songer et al. 2002).

The FI³T project design and implementation activities described in this chapter and the highlighted research findings from the FI³T research provide a potential to address the need for designing and implementing technology-rich STEM learning activities that promote successful learning in K-12 education. The author of this chapter hopes that the writings and discussions in this chapter provide guidance for educators who are interested in offering similar STEM learning projects; inform school-level decision makers and funding agencies about research-based best practices in STEM programming; and support higher education faculty in their thinking about developing further grant and research proposals that involve K-16 collaborations.

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