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Integration of Innovative Technologies for Enhancing Students' Motivation for Science Learning and Career

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Abstract This paper analyzes the outcomes of an innovative technology experience for students and teachers (ITEST) project, Mayor's Youth Technology Corps (MYTCs) in Detroit, MI, which was funded by the NSF ITEST program. The MYTC project offered an integration of two technologies, geographic information system (GIS) and information assurance (IA), to stimulate students' interests in science, technology, engineering, and mathematics (STEM) career pathways and learning opportunities among high schools in underserved communities of the City of Detroit. Pre- and post-surveys demonstrated that the MYTC students showed growth in nearly every area covered in the surveys, including dispositions about STEM career and learning. A STEM career goal measure showed that overall interest in having a career in STEM increased 9 % throughout the program, with an additional 10 % for those who participated in an internship experience, the capstone of the MYTC project.

Keywords Science education · STEM career · Student motivation · Geo-spatial technology · Information assurance · Innovative technology · Future career · Low-income cities

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Introduction

Current literature reveals that classroom science engages only a small percentage of students and involves even fewer low income, female, or minority students (Tobin 2005; NRC 2011). 83.7 % of the total population (617,832) of the City of Detroit is African American (USCB 2013). Creating and enhancing resources and exposures for 65,632 high school students between 15 and 19 in Detroit (USCB 2013) to careers in science and technology is an extremely challenging but necessary task. The Mayor's Youth Technology Corps (MYTC)—Creating Safe Communities through Information Technology Training in Homeland Security Applications (2008–2011) offered a collaboration of resources, supports, and opportunities for strengthening STEM education efforts for high school students throughout underserved communities of Detroit.

The MYTC project was a joint effort among Eastern Michigan University, Detroit Public Schools and the City of Detroit Office of Homeland Security and Emergency Management. The project was funded during 2008–2011 by US NSF Innovative Technology Experience for Students and Teachers (ITEST) Program. The ITEST program was established in 2003 by US NSF to address the looming shortage of technology workers in the United States. The ITEST program is funded by H-1B visa revenues in direct response to the need to ensure a high-quality future STEM and ICT (information and communications technology) workforce that can meet US technology needs (Newson 2012). The ITEST program has three distinct goals (NSF 2012, p. 3):

1. To develop, implement, study, and evaluate interventions that encourage K-12 students to develop interest in and to be prepared for careers in the STEM and ICT workforce of the future.

2. To produce research findings that build knowledge about approaches, models, and interventions involving K-12-aged children and teachers that are most likely to increase the nation's capacity and innovation in the STEM and ICT workforce of the future.
3. To equip teachers with the resources to ensure that their students consider choosing and are prepared to enter the STEM and ICT workforce of the future.

Through September 30, 2012, 193 ITEST projects were funded across 42 states; 225,800 K-12 students received STEM and ICT training opportunities; and more than 8,000 educators from both K-12 schools and colleges were involved (LRC 2012a). The snapshots, overviews, and abstracts of all ITEST projects can be found on the Website of the ITEST Learning Resource Center (LRC 2012b).

Mayor's Youth Technology Corps (MYTC) was a student-focused project developed to meet the first goal of the ITEST program comprised of four important goals: (1) Creating career pathways for two cohorts of 50 high school students (100 total) in information assurance (IA) and geographical information system (GIS) in the context of application development concerning homeland security and facility management; (2) providing students with inquiry-based STEM learning opportunities through multiple delivery methods; (3) enhancing students' hands-on working experiences by offering internships in City of Detroit governmental agencies; and (4) providing college experiences for the students.

The MYTC project goals were achieved through a variety of programs, such as summer institutes, after-school online programs, in-school classroom sessions, summer internships, and university residency (Table 1). At the end of the MYTC project, 814 students participated in various activities sponsored by the project and more than 20 teachers served as lead teachers. Among them, 162 students graduated from the summer institutes, 120 students completed in-class, after-school, or online GIS training courses, 84 students went through a hybrid information assurance course, and 98 students successfully finished their internship assignments. A STEM career goal measure showed that overall interest in having a career in STEM increased 9 % throughout the program, and an additional 10 % as a result of the internships.

This paper addresses how technologies were integrated by the MYTC project team to foster students' interests in STEM career pathways and in STEM learning opportunities. The compelling nature of IA and GIS technologies and the added value of the integration into career development will be discussed in section "IA and GIS: STEM Career Pathways." The unique contributions of IA and GIS in STEM learning and teaching will be analyzed in section "IA and GIS: STEM Learning Opportunities." The impacts of IA and GIS on the students' attitudes toward STEM learning and career will be examined in section "Survey Design and its Result Analysis." The lessons learned and future improvements will be discussed in the final section.

Table 1 The summary of MYTC project activities and participations

Activities/participation	Cohort 1		Cohort 2[a]	Subtotal
	Year 1	Year 2	Year 3	
Student participation (total 814)[b]				
Summer institutes	53	59	50	162
After-school programs	53	197	68	318
In-classroom sessions	0	250	84	334
Student completion (total 464)[c]				
Summer institutes (40 h)	53	59	50	162
Information assurance (100 h)	0	0	84	84
GIS training (100 h)	0	52	68	120
Internships (120 h)	0	41	57	98
College experience[d]	53			
Teacher leaders and trainers	3	13	4	20

[a] Cohort 2 was running from Year 3 to the first quarter of Year 4 with a no-cost extension

[b] The student participation data were repetitive within each cohort and between different activities. For instance, a student in Cohort 1 could participate in summer institute, after-school program, and in-class course. The accounting could be double- or triple-counted

[c] The students who completed a program were part of the participants

[d] The first summer institute was conducted on Eastern Michigan University campus and 8 college students were recruited as chaperons. The campus residency was eliminated from the second year due to the safety and budget considerations

IA and GIS: STEM Career Pathways

At the beginning of the new millennium, information technology (IT) was exploding. Three occupations related to IT were listed among the top ten fastest growing occupations: the employment in network systems and data communication analysts was predicted to grow 57 % from 2002 to 2012 (the second fastest), the employment in computer software engineers—applications 46 % (the eighth), and the employment in computer software engineers—systems software 45 % (the ninth) (USDL-BLS 2004). Even after the economic recess 2007–2009, computer system design and related services were still listed as the eleventh among the top 20 industries with the largest projected employment growth 2010–2020 at an annual growth rate 3.9 % (USDL-BLS 2012).

The fast growing IT industries has exhibited great impacts on education. A variety of tools and applications of IT were introduced to automate information delivery functions in classrooms (Leidner and Jarvenpaa 1995; Tomei 2012). Many efforts were made to integrate IT approaches and tools to transform education. For instance, mobile serious games (MSGs) were used as primary platforms to implement a series of learning activities for secondary students for the development of problem solving and collaborative skills (Sánchez and Olivares 2011). Blogs, MS PowerPoint (PPT), and the Internet were used as learning tools for project-based learning in the sixth grade classroom (Wang et al. 2012). IT-embedded environmental research projects were used as primary materials of professional development (PD) for secondary science teachers (Ebenezer et al. 2012). The effectiveness of PD was improved based on the assessment of how the science teachers subsequently engaged students with these projects in classrooms. The presentation of multimedia in the form of maps reflects an innate human tendency with both sociocultural dimensions and technical functions (Literat 2013).

For the STEM career incentive, we integrated two specific IT technologies, information assurance (IA) and geographic information systems (GISs), which have been in great demand in job markets. IA is an academic term of cybersecurity, which is increasingly becoming a national security concern. Cyberattacks on federal agencies and large corporations have jumped dramatically in recent years. However, our country's cyberdefenses are not keeping up; as Secretary Panetta recently warned that a "Cyber Pearl Harbor" could be more catastrophic than the terrorist attacks of 9/11 (Bergersen et al. 2012). In order to thwart such an attack, President Obama signed the cybersecurity executive order. This executive order instructs to set up the foundations, in which a "framework" can be constructed so that intelligence sharing among the federal agencies and private sector industries will be enhanced to improve cybersecurity (Whittaker 2013). In fact, the US government has been expanding its cybersecurity expenditure despite the economic slowdown and the recent sequestration (MRM 2013). During the period 2013–2018, the cybersecurity industries will have a cumulative market value of $65.5 billion. The US Federal cybersecurity market will grow steadily at about 6.2 % (compound annual growth rate) over the next 6 years. Another statistic details that the United States needs up to 30,000 highly trained cybersecurity specialists to protect the government and large corporations. Now there are only about 1,000 (Beeler 2010).

On the other hand, "Geographic information systems (GISs)—and the analytical tools for using these systems wisely—now play a fundamental role in the provision of emergency services, transportation and urban planning, environmental hazard management, resource exploitation, military operations, and the conduct of relief operations. In the years ahead, geographical tools and techniques will be of vital importance to the effort to monitor, analyze, and confront the unprecedented changes that are unfolding on Earth's surface (NRC 2010a, p. ix)." Because the uses for GIS are so widespread and diverse, the market is growing at an annual rate of almost 35 %, with the commercial subsection of the market expanding at the rate of 100 % each year (USDL-ETA 2010). Geospatial (GIS, GPS—global positioning system, and RS—remote sensing) technology, along with nanotechnology and bio-engineering, is cited as one of the three emerging industries in *Nature* (Gewin 2004).

In addition to the fact that IA and GIS are the two strong programs at Eastern Michigan University, the integration of IA and GIS brought added values to the MYTC project. The advantage of the Internet, i.e., global and real-time accessibility, ensured a remarkable growth in Web GIS. Almost all enterprises are using the Internet to disseminate location-related (geographic) data in map forms using Web GIS (Green 1997; Rohrer and Swing 1997; Peng and Tsou 2003; Baker 2005). With the increasing popularity of global online mapping web applications (e.g., Google Maps, Microsoft Virtual Earth, Yahoo Maps, ArcGIS Online), Web GIS is part of "business exchange," and there is an ever-growing volume of literature and public participation (Carver 2001; Clark et al. 2007; Kulo and Bodzin 2013). On the other hand, the geographic data (including raster data, vector data and attribute data) of Web GIS face great potential security challenges. Web GIS becomes a hot front of information assurance research in order to avoid disastrous results that a security leak may bring (Li et al. 2009; Kim et al. 2013). The integration between IA and GIS has never been stronger or more in demand by leading companies. An example is a recent web posting for General Dynamics—a GIS System Administrator with information assurance knowledge who would oversee DoD Enterprise servers (GDIA 2011).

IA and GIS: STEM Learning Opportunities

The roles that IA and GIS can play in education are tremendous. Since IA (i.e., cybersecurity) concerns an emergent national security, there is an urgent need for teaching IA in K12. However, IA is still a new subject in K-12 curriculum. According to Zogby (2011), a survey released by the National Cyber Security Alliance (NCSA) and supported by Microsoft reported that "more than three quarters of US teachers have spent fewer than 6 h on any type of professional development education related to cyberethics, cybersafety, and cybersecurity within the last 12 months; more than 50 % of teachers reported their school districts do not require these subjects as curriculum; and only 35 % taught proper online conduct." Despite prevalent support by school administrators and teachers for cyberethics, cybersafety, and cybersecurity, there is a shortage of teachers who are qualified to teach their students in these topics.

Based on the above, and considering the current shortage of qualified teachers who can educate their students in Cyber Security, the MYTC project provided a teacher-centered Cyber Security educational program and ensured continued teacher learning (Guskey and Yoon 2009; Hawley and Valli 1999; Scher and O'Reilly 2009). It is also worth pointing out that due to the shortage of qualified teachers, the MYTC project revised its original implementation plan, and postponed the student training in IA to the third grant year. Instead, the MYTC project only introduced the topics of network security and computer forensics at the summer institutes but focused on student training in GIS during the grant years 1 and 2. Meanwhile, the MYTC project provided PD in network and forensics for the lead teachers.

Geographic information system (GIS) has long been recognized as an interdisciplinary technology supporting high-level thinking and spatial reasoning (Bednarz 1995; Drennon 2005; NRC 2006; Rye et al. 2012; Kulo and Bodzin 2013). GIS has been commonly regarded well suited to conduct open-ended investigations, to visualize complex real-world problems, and to support multiple modes of learning (Hunter and Xie 2001; Henry and Semple 2012; Lay et al. 2013). GIS has been widely deployed by teachers and educators to teach subjects in social studies (Donaldson 2001) and, in particular, in geography. GIS, along with its related methods and datasets, has opened the "door" to geography education (Getis 2008). GIS enables educators to process knowledge beyond traditional school-based geography toward spatial problem solving (Bednarz and van der Schee 2006). GIS is envisioned as an invaluable resource for use in extending a learner's understanding of geography as it allows for the visual illustration, and manipulation of central concepts of the discipline (Breetzke et al. 2011, p 148).

Learning, using, and problem solving with GIS and IA provide cogent and relevant contexts for students to develop computational thinking skills, a set of skills, habits, and approaches that are integral to solving complex problems using a computer and widely applicable in the information society. These skills, many of which are critical to tomorrow's workforce but not taught in schools, draw on the concepts that are fundamental to computer science, and involve systematically and efficiently processing information and tasks (Wing 2006).

Mayor's Youth Technology Corps (MYTC) learning strategies embraced and supported many of the critical benefits associated with computational thinking, such as succeeding in a technological society, enabling individuals to navigate more effectively through a society in which they frequently encounter technological devices in their personal lives, having the ability to take advantage of technological resources (e.g., information on the Internet, social networking, online education, cloud computing), and being better able to understand the ways in which technology is relevant to public policy decisions (NRC 2010b). The authors argue that computational thinking increases interest in IT professions, helps maintain and enhance US economic competitiveness, supports inquiry in other disciplines, and enables personal empowerment (ibid).

Despite a national trend of increasing adaptation of GIS in K-12 curricula and extracurricular activities, the use of GIS-based technologies to reinforce temporal and spatial content in K-12 education has been sporadic. Results from a national study conducted in 2000 revealed that of the 1,900 US high school classrooms with access to GIS, <15 % reported ever using the technology for instructional purposes (Kerski 2000). This is despite the fact that research shows that GIS can be used beneficially to aid in the teaching and learning of geography and history, and that internet-based and desktop GIS can be integrated relatively simply into primary and secondary curricula (Bednarz and Ludwig 1997; Kim et al. 2013; Niedomysl et al. 2013). Thus, it has been recommended that the perceived usefulness and school support are important factors influencing teachers' adoption of GIS (Lay et al. 2013).

All of the above developments led to a unique position in City of Detroit for integrating IA and GIS to motivate students' interests in STEM learning and career. First, Detroit is an important port city between the USA and Canada. Homeland security has been a top priority since the 9/11 terrorist attack. There is a shortage of information technology workers in the city agencies that deal with homeland security and emergency responding. Second, mapping for critical facilities, crime hot spots and emergency responses is an essential element of information technology tasks in these city agencies. These agencies have strong demands for employees and interns to have an integrated knowledge of IA and GIS technologies. Third, it is worth pointing out that surfing on the Internet and finding out how to protect personal information on Websites is a fun activity. For many youths, a draw to science inquiry and engineering experiment could be simply a project that looks like fun (Boss 2013). Learning network security and computer forensics with their peers is particularly appealing to them. Fourth, demonstrating bright career opportunity is particularly an effective way to motivate youth in an underserved community (like City of Detroit) into STEM learning. In other word, what the MYTC project was implementing is thus linking current specific plans and actions to future desired goals (Stake and Mares 2005) for its participants.

In summary, the integration of IA and GIS as the demonstrations of STEM career to the urban youth in City of Detroit is purposefully focusing on the societal and cultural dimension of information technologies (Leidner and Jarvenpaa 1995; Kali 2002; van Eijck and Roth 2007). Both IA and GIS applications were pertinent in City of Detroit and, therefore, "the place-based learning" could be adopted to establish natural linkages between technologies and neighborhood socioeconomics (Elder 1998; Krapfel 1999; Wessels 1999). In other words, the project activities would occur in students' milieu. As students participated in project activities (i.e., learning IA and GIS and applying them in the city departments), they would enhance their STEM learning by becoming community citizens and by helping the hiring agencies to conduct IA- and GIS-related jobs or tasks. Thus, the project provided an opportunity for students to use their own community as a platform for learning, which allowed them to create "a set of building blocks from which to construct a life" (Nabhan and Trimble 1994, p. 131).

Survey Design and Its Result Analysis

Survey Design

Among several goals of the MYTC project, the project's primary objective was to stimulate students' interests in STEM career and STEM learning opportunities among high schools in the City of Detroit. The project was designed to achieve its goals by improving STEM skills, specifically in IA and GIS technologies, and improving STEM career opportunities for the Detroit area urban youth population. In order to measure how the MYTC project motivated students' interests in STEM career and learning, three sets of tests were developed under the guidance of Simpson–Troost Attitude Questionnaire (STAQ) (Simpson and Troost 1982; Simpson and Oliver 1985) and Baker's Attitude Toward Science in School Assessment (ATSSA) (Baker 1985). A good literature review about STAQ was provided by Owen et al. (2008) and Liaghatdar et al. (2011).

To examine the impacts of the integration of IA and GIS on students' motivation on STEM career pathway and learning opportunities, we used a three-phase research design that took into consideration a broad survey and a focused interview (Table 2). First, an online survey concerning the students' STEM attitude disposition (Table 3) was conducted for students who either registered for summer institute, or for GIS-100 class (a hybrid online and-face-to-face GIS course requiring 100 attendance hours to complete), or for IA-100 class (similar to GIS-100). The summer institute, GIS-100, and IA-100 were the core MYTC training activities. When a student successfully completed any of them, s/he would receive a completion certificate and a nominal stipend. Moreover, the completion of either a GIS-100 or IA-100 was a prerequisite for enrolling into the summer internship program so that a student would have required skills to complete an internship assignment either in GIS or in IA field.

Table 2 The sample sizes surveyed in each year

	Year 1	Year 2	Year 3	Total
The number of students surveyed	65	154	69	288
Surveyed (%)	61	30	34	35
The number of students interviewed	19	100	32	151
Interviewed (%)	18	20	16	19
Total participants in Cohorts 1 and 2	106	506[a]	202[b]	814

[a] The participants in Years 1 and 2 were in Cohort 1. Around two-dozen participants in Year 1 continued the program in Year 2

[b] The participants in Year 3 were in Cohort 2, who were recruited from different schools

Table 3 STEM attitude disposition survey

Survey questions	Year 1 (%)	Year 2 (%)	Year 3 (%)
I want to know how computers and GIS can help design cars	50	36	46
I want to know how computers and GIS can help design cities	47	42	33
I'd like to figure out how to program computers	28	37	36
I'd like to see inside of electronic toys	26	28	33
I think computers and GIS can be used to help disaster victims such as those from Katrina	23	39	28
I would like to listen to scientists talk about their jobs	13	19	14
It is BORING to learn science in school	8	11	8
I probably won't get a job in science	7	8	0
Engineering and science magazines and stories are interesting	3	3	3
I follow computer science blogs	3	3	3

The second phase involved a focused individual interview for a group of students who were selected by a semi-stratified random sampling (Table 4; Fig. 1). The candidate students were those who finished the summer institute, or were in one of the two courses, GIS-100, and IA-100. Interviews were conducted by the external evaluator. A student was selected on the basis of the candidate pool, the grade, the gender, and in consultation with the lead teacher from the student's home school. It is worth noting that there was a high dropout rate in Cohort 1. Thus, the MYTC project made several rounds of new recruitment in the latter

Table 4 The MYTC focused student interview concerning STEM career, interest and obtained knowledge[a]

Interview questions	Short forms	Cohort 1		Cohort 2	
		Year 1-Pre	Year 2-Post	Year 3-Pre	Year 3-Post
I am interested in forensics	Forensics interest	3.3	3.2	2.9	3.2
I am interested in college experience	College interest	3.3	3.4	2.3	2.5
I like mathematics	Like math	3.2	3.3	2.9	3
STEM is my career goal[2]	STEM career	3.2	3	2.4	2.8
I like science	Like science	3.1	3.2	2.7	3.3
I enjoy my involvement in MYTC program	MYTC involvement	3	3.3	2.8	3.1
I am interested in network security	Network interest	2.9	3.1	2.3	3.3
I am interested in GIS	GIS interest	2.8	3	2.7	3.2
I have some knowledge of forensics	Forensics knowledge	2.8	2.6	2.8	3.1
I improved my general tech level through MYTC program	Tech improvement	2.7	2.5	2.7	3.1
I enjoyed the integration of various MYTC technologies	Tech integration	2.6	2.2	2.2	2.9
I have some knowledge of GIS	GIS knowledge	2.6	3.2	2	2.8
I have some knowledge of network security	Network knowledge	2.6	2.5	2.9	3.5

[a] 19 students in Cohort 1 were interviewed for the pre- and post-tests, while 32 in Cohort 2

[b] 9 % of the 51 interviewed students changed their attitudes toward STEM career, from "dislike" at the pre-test to "very like" at the post-test

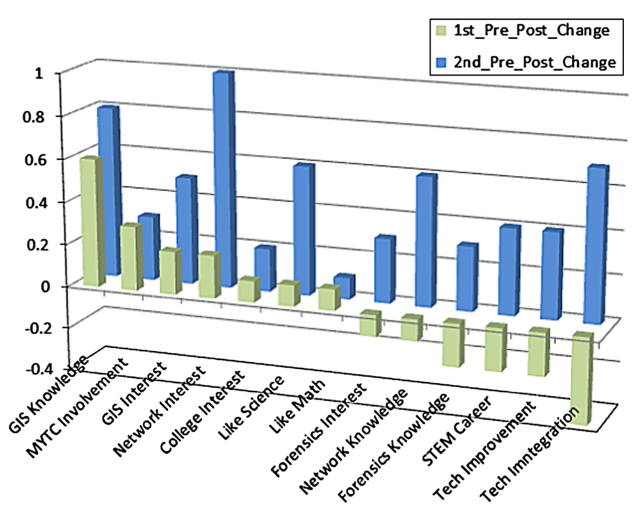

Fig. 1 The changes between the pre- and post-test interviews

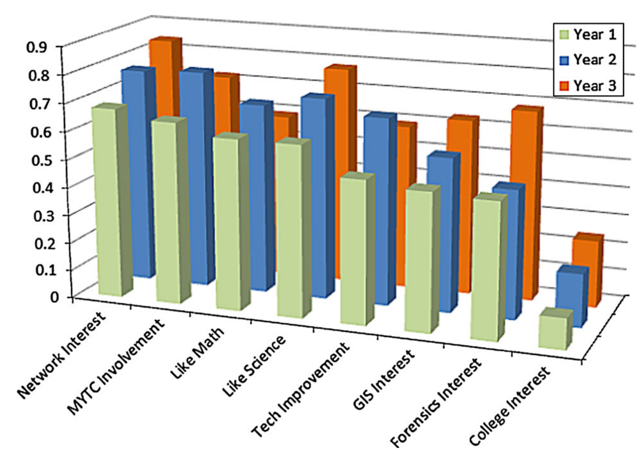

Fig. 2 The correlations between the STEM career and the interview questions. The y axis is labeled as the correlation coefficients with the variable, "STEM career." The statistical significance is at 0.01 when the coefficient is higher than 0.45; at 0.05 when the coefficient is between 0.25 and 0.45; and at 0.1 when the coefficient is between 0.1 and 0.25. The sample size is reported in Table 1

part of Year 1 and early Year 2. As a result, the MYTC project had a much larger Cohort 1. Furthermore, as part of the interview analyses, a correlation analysis was carried out between the variable of STEM career goal and the variables of STEM dispositions (for details see Fig. 2).

In the third phase, a small group of selected students who successfully completed the MYTC internship program with City of Detroit governmental departments was interviewed. This interview was designed to collect students' reflections concerning the internship and STEM career connections (for details see Fig. 3). However, due to the small sample size, the result is informative but not statistically substantiated.

Results and Analyses

The general STEM attitudinal survey was conducted online immediately before students began their participation in either summer institute or GIS-100 or IA-100 training programs. These pre-test data provided a valuable baseline picture of students' thoughts relevant to this project (Table 3). The interests of knowing how computers help design cars and cities were among the highest. Since Detroit has long been recognized as the historic heart of the US automotive industry, it was no surprise that the students' interest in cars was the top one. Also they were

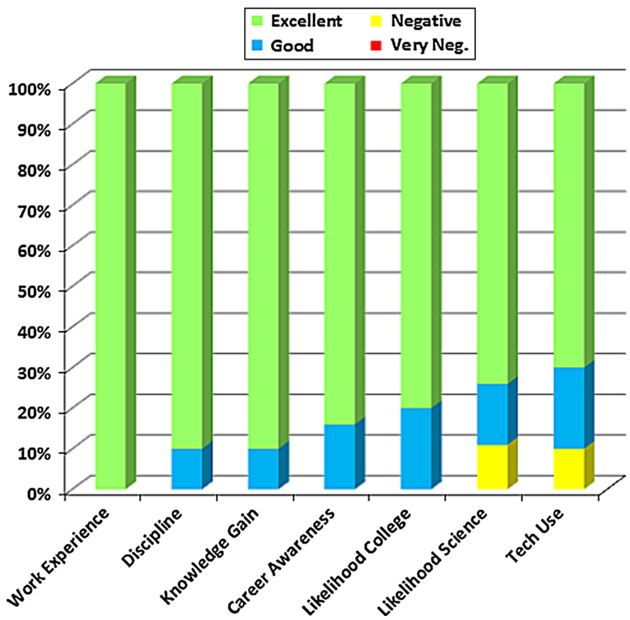

Fig. 3 Students' workplace experiences as a result of internship ($n = 27$). 10 % of the 27 interns expressed a significant change in their determination to seek STEM career in the future because of their positive experience gained in the internship

urban youth and thus the term of city was a very familiar one to them. The next highest group of survey responses was related to the perceptions concerning computer programming, curiosity of exploring electronic toys, and assistance of computers and GIS to disaster relief. These suggest that students were entering the program with an adequate awareness of the possible uses of computer and GIS technologies, and a greater inherent interest toward technology.

It was interesting to note that there were a certain percentage of students who liked to listen to scientists talk about what they were doing. However, there were a comparable percentage of students who thought that it was boring to learn science education in school. This contrast could be attributed to students' interest in learning science from scientists, researchers, and practitioners.

In the next group of responses (not getting a job, reading magazines, and following blogs in science), low percentages were observed, which led to two possible explanations. First, not many students excluded science as a career pathway. Second, few students were showing extreme interests in pursuing engineering and science at that time. A final note was that the general students' attitudinal dispositions to different survey questions formed a clear pattern as we described above, although there were variations in students' responses in different grant years. Since the surveys were pre-test only and the survey samples were not strictly controlled, it would not be meaningful to attempt to explain the yearly variations.

With regard to the focused (including both pre- and post-) interviews, the samples were evenly distributed across grade level and gender. Responses were coded and emergent themes identified. From the questions (Table 4), the following dimensions emerged: career goal, general technology level, familiarity with MYTC technologies, appeal of science and mathematics, knowledge and interest in GIS, network security, computer forensics, why they joined MYTC, and college experiences. A rating was developed using a 0.0–4.0 scale to allow students to express their reflections or judgments to various interview questions. The 4.0 scale was analogous to a five categorical evaluation system: 0.0—extremely dislike, 1.0—dislike, 2.0—neutral, 3.0—like, and 4.0—extremely like. Moreover, the 4.0 scale enabled students to accurately report their reflections about an interview question. For instance, a student could slide a score between 2.0 and 3.0 to express her/his subtle feeling between "neutral" and "like."

The interests in computer forensics and college experience were the highest rated category in the pre-test interview of Cohort 1, reflecting the students' enthusiasm for the Forensics Introduction Session and the students' excitement living in college campus dormitory during 2008 summer institute, when the pre-test interview took place. The students' fondness in math, STEM career, science, and the MYTC project was also rated very high. In general, the students expressed positive opinions toward the remaining pre-test interview questions of the MYTC project (Table 4).

The changes between the pre- and post-test interviews were interesting and warranted further discussion (Fig. 1). For Cohort 1, the first terrace of improvements between the pre- and post-tests consisted of GIS knowledge and enjoyable MYTC involvement. The second level of improvements included students' interests in GIS and network security technologies. The students' fondness in college experience, science, and math was also improved. These improvements were consistent with the goals of the MYTC project. In particular, due to the adjustment of the MYTC project implementation strategies, GIS training sessions and GIS-100 courses were the primary training activities in Years 1 and 2 (Table 1). Consequently, the students were happy with their gained knowledge in GIS and enjoyed their involvement with the MYTC project. In return, students' interest in college experience, science, and math was elevated.

On the contrary, three negative terraces were revealed in the differences between the students' pre- and post-test interviews in Cohort 1. The worst one was the integration of MYTC technologies (GIS and IA, which was implemented in the MYTC as two subjects: network security and computer forensics). The next one was comprised of the knowledge gained in computer forensics through the MYTC project, the prospect of STEM career, and the general technology improvement. The third one included the students' interests in forensics and gained network knowledge. The negative changes reflected by Cohort 1 were mainly caused by the delay of offering an IA course covering the basic knowledge and skills of network security and computer forensics. As discussed before, the MYTC project witnessed a high rate of dropout in the later part of Year 1 and had to provide PD opportunities for the lead teachers to become acquainted with IA. Therefore, the plan of offering an IA course (IA-100) was subsequently delayed until the beginning of the third grant year. As a result, the students interviewed by the project evaluation team in Cohort 1 showed apparent frustration about the delay, which was reflected in the post-test interview.

The MYTC project resulted in significant improvement for Cohort 2 participants. All MYTC program areas received enthusiastic response by the participating students. In particular, the students' perceptional changes between the pre- and the post-tests got the highest scores (0.6–1.0 increases in the 4.0 scale) in the interest in network security, the gained GIS knowledge, and the appreciation of MYTC technology integration (Fig. 1). The next group of the students' assessments included the fondness in science, the gained knowledge in network, and the GIS interest (0.4–0.6 increases in the 4.0 scale). The STEM career, the general technology improvement, the enjoyment of MYTC involvement, the forensics interest, and the gained forensics knowledge achieved 0.2–0.4 increases in the 4.0 scale. Although the college interest and the math fondness were the members of the last group, positive increases were still observed.

We conducted a correlation analysis to examine the behavior of the variable of STEM career goal in relationship with other interviewed variables (Fig. 2). Instead of using the pre- and post-tests in a comparison mode, all pre- and post-interview responses were regrouped by the year when the interviewed students joined the MYTC project. In this way, we got a much larger dataset in order to increase the statistical confidence levels. The correlation analysis confirmed that those students who thought about career goals with respect to STEM pathways also had a high desire in network security applications, liked science, and enjoyed involvement with the MYTC program (the correlation coefficients were close or above 0.7). Next, those students felt confident with general technology skills, showed a strong interest in GIS, and liked math (the coefficients were close or above 0.6). One unique finding was that those students in the third year demonstrated a strong interest in computer forensics (the coefficient reached 0.67) because it was offered in Year 3. The least related variable to a strong career goal was college experience. The explanation was straightforward because the college experience (on-campus residency) component was removed from the MYTC project due to the budget limitation and the safety consideration. Several interview questions were not shown up in Fig. 2 because their statistical significance levels were >0.1. In other words, their correlations with the career goal were not statistically significant.

The internship program was an important and unique component of the MYTC project. Active workplace internships were granted to students who completed basic GIS or IA training, who demonstrated competency for the tasks demanded, and who were prepared for the workplace with adequate discipline and ethnics. As a technology-based STEM program aiming to encourage and stimulate students into thinking about continued study in the sciences and technology, the internship experience may provide the critical link from learning and knowledge gain to application and practice. The internship placements were at actual jobsites hosted by a range of municipal departments (ten in total) of the City of Detroit:

- Governor's Office in Southeastern Michigan.
- Department of Environmental Affairs (DEA).
- Homeland Security and Emergency Management (HSEM).
- Water and Sewage Department (DWSD).
- Health and Wellness Promotion Department (DHWP).
- Information Technology Service (including a division of GIS).
- Detroit Public Lighting.
- Detroit Fire Department.
- Creative Communications Services Department.
- Department of Transportation.

In addition to gaining practice using technology skills acquired in the program, students learned about the workplace culture, including discipline, respect, how to dress, how offices and departments function, and a range of other operational and experiential details not easily communicated in a typical school setting. Student interns completed 120 h of job tasks over eight weeks and received a stipend for their efforts.

Notably, the work experience and the knowledge gained were the highest categories (Fig. 3). Career awareness, an important component of ITEST showed high "excellent" and "good." It is worth pointing out that 10 % of the interns who were interviewed said explicitly that because of the internship experience, they decided to seek the STEM career. Students felt that the experiences helped them prepare for their next stages, whether in school, the workplace, or college. Figure 3 was the composite result of the interviewed interns in Years 2 and 3. When we analyzed both years of internships to date, the order of ranking changed slightly. We noticed that work experience was still rated the highest, but it was followed by "attaining discipline" as a leading positive experience from the internship. Next were "knowledge gain" and "career awareness," which moved up significantly, an element of the ITEST program, and also a primary intent of the internship component.

Conclusions

Two technologies were integrated in the MYTC project as incentives to stimulate the interests in STEM education and career for urban youth in an underserved community, City of Detroit. GIS (geospatial technology) provided students not only with technical skills, but also presented topics of inquiry that were relevant to their backyards. These real-time linkages between technologies and the issues facing their own communities enabled students to learn STEM by becoming community citizens and helping their communities. In addition, GIS promoted the development of analytical skills and proved to be an inroad toward inquiry thinking and learning.

Information assurance (IA) technologies (including network security and computer forensics) demonstrated to the students the complexity of communications technology and its weaknesses and vulnerabilities. In the MYTC training, IA was taught in a civil society index (CSI) framework, connecting lessons to popular culture, but also to real-world scenarios that were increasingly compromising the networked world. In doing so, students became engaged in an area of engineering previously unknown, but extremely relevant and valuable for their career futures. Moreover, the integration of IA and GIS enabled students to learn technology in sophisticated environments (Web GIS involved global enterprise GIS systems and network security). Students began to make sense of how technologies were connected and behaved. Both technologies supported and increased computational thinking skills.

Students of the target population (typically underserved urban youth) had great potential and drive when it became clear to them that the learning materials were relevant and technological, and would increases job and career opportunities. In addition, internships provided a critical platform for students to immediately demonstrate and put to use their newly found knowledge, all while contributing useful work to City of Detroit infrastructure and getting paid to do so. Furthermore, interns built up resumes, established professional contacts, and gained on-the-job experiences beyond those technological. Ideally, a program related to building STEM skills toward career alignment should have an internship component.

In short, the MYTC's impact on participants, as described by the data analysis in section "Survey Design and its Result Analysis," increased students' interest and knowledge in those STEM topics and knowledge areas related to MYTC: namely geospatial technology applications and information assurance, the primary content areas of the grant. As a result of the internship opportunities and the GIS + IA workplace opportunities afforded to participants, students started seriously thinking about STEM workplace career options in tangible ways, including future study.

However, there were several takeaway lessons from the MYTC project. First, entering students had a limited knowledge of geospatial concepts and information assurance skills. It was critical to have a well-structured and articulated offering of GIS and IA courses in order to help the students to learn technology in sophisticated environments. The interruption of the course offering sequence caused by the discontinuity of student participation in Cohort 1 and the lack of knowledgeable teachers in IA had a negative impact on achieving the project goals.

Second, additional financial resources reallocated to the recruitment of students in Cohort 1 forced the project to eliminate the on-campus residence component from Year 2. This adjustment helped to recruit more students to participate in the training and internship activities, but cut off the connection between STEM education and college experience.

Third, the internship program was proved to be one of the most compelling and rewarding components of the MYTC model. The offering of the paid internship to students who came from disadvantaged families not only helped the students to nurture their interests in STEM career and education, but also won the support from students' parents and communities. The MYTC project provided funding to City of Detroit municipal departments to hire participating students as interns; in turn students contributed to real-world infrastructure problems and solutions. The scalability will depend upon local municipal needs and resources to support paid internships, which has not been explicitly addressed in this paper and will be a research topic in the near future.

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