Lessons Learned Using Health Information Technology to Foster Student Interest in STEM Majors and Careers

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In this paper, the authors describe their efforts to create a high school/post-secondary extracurricular program to encourage students to pursue STEM (Science, Technology, Engineering, and Mathematics) studies and careers. The program, Best We Can Be, uses Health Information Technology (HIT) as a foundation from which students can explore diverse topics and interdisciplinary connections. It gives students opportunities to participate in collaborative team efforts. Specific topics are selected based on input from subject matter experts, suggestions from the students' teachers, and self-reported student interests. Best We Can Be sharpens the focus of students' view of their opportunities. The oft-given advice, "Just follow your passion!" does not help students make optimal, rational college and career choices. Students are often unaware of their options and lack the skills to capitalize on them. Best We Can Be uses an online data collection platform to examine the feasibility and usefulness of different criteria to measure student needs and best teaching practices.

Calls for educational reform and revolutionary approaches to teaching STEM have been ongoing for decades. Recently, this has translated into action—as reflected in the explosion of new STEM programs within and outside traditional school structures. The need for effective programs that engage students in STEM learning is clear and urgent. However, as more programs are developed, we see increased competition for funds and students' attention. Better yardsticks are needed to enable informed choices. Evaluating program impacts and quality requires universal metrics and data collection that enable a consistent and holistic perspective. Ultimately, evaluation and assessment of STEM teaching programs contributes to greater understanding of the complexities and interdependences found in educational settings. This understanding is indispensable to creating a workforce with the requisite STEM skills needed to succeed in today's society.

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Introduction

Why do students choose to study STEM, or not? Although we may know the reasons for our own choices, on the whole, it is a mystery. "Most research centers on persistence and attainment among students who have already entered the STEM fields. Not as much empirical attention has been paid to factors relevant to interest in, and entrance into, STEM fields, which are arguably the first critical steps into the STEM pipeline" [1].

Many pathways lead students to study STEM. One of the strongest predictors of interest in STEM is early success in mathematics. Mathematics proficiency builds confidence and skills needed across all STEM disciplines [1]–[6]. Parents, teachers, guidance counselors, and professional role models influence student interest in STEM. These influences may work either way—and a bad experience may permanently dissuade an otherwise promising student from pursuing studies in STEM.

Research shows that as students, especially women and minorities, progress from elementary to high school, their interest in STEM declines precipitously [1]-[3]. Upon graduation from high school, a majority of United States students lack basic STEM skills, and are poorly prepared for college and careers [7]-[8]. At the undergraduate level, up to 60% of students who start in STEM switch majors or drop out without completing any degree. At the graduate level, foreign students earn more than half the advanced degrees in many STEM fields. Women and minorities are consistently underrepresented in many traditional STEM disciplines [9]-[11]. In today's technological society, this has critical implications for students' future well-being and advancement prospects. It is well documented that the best jobs—based on salary, advancement prospects, and job availability—today and in future will go to people with the required STEM skills [12]-[14].

These findings provoke many questions: Why are students doing poorly in high school? Why are students leaving STEM majors once they are in college? Why are foreign-born students more likely to declare STEM majors? Why are there gender differences? What can be done to improve student performance and interest in

STEM? This paper describes the authors' attempts to answer these questions.

What is Best We Can Be?

Best We Can Be is an after-school and summer program conceived in collaboration with the Academy of Information Technology and Engineering (AITE) high school. AITE is an inter-district, public, magnet high school located in Stamford, Connecticut serving approximately 650 students. According to its website, AITE "offers a dynamic college preparatory environment that integrates 21st century learning expectations, world language acquisition, emphasis on global competencies, advanced information technology skills and knowledge, introductory courses in pre-engineering and architecture, and service learning. … All students and teachers are provided with wireless PC tablet computers that promote inquiry, creativity, and collaboration [15]."

AITE, like many schools, struggles with competing priorities and preparing its students to do well on standardized tests. There is little money and latitude for new programs. It's much easier to experiment with novel learning approaches in extracurricular programs. Recognizing this, the school principal and the technology, business, and science teachers worked with the authors to create **Best We Can Be**. These are the program goals:

- Be responsive to student and parent requests for more extracurricular STEM learning experiences;
- Encourage student exploration of STEM disciplines and careers;
- Reinforce student learning of school curriculum;
- Foster participation of girls and under-represented minorities in STEM activities;
- Build critical skill sets needed for college and careers;
- Motivate students to take responsibility for their own learning.

Student surveys conducted at AITE reveal high interest in STEM extracurricular activities, especially those relating to healthcare and information technology. This inspired a focus on Health Information Technology (HIT) as a way to engage students with diverse interests across all grade levels. Thus, the **Best We Can Be** health information technology (HIT) program was officially launched the summer of 2012, and offered to all interested AITE students free of charge.

Most students participating in the program say they want to pursue a career related to healthcare—as a doctor, nurse, physician assistant, biomedical engineer, or as an information technology professional. Some say they have no idea what they want to study in college and are looking for inspiration on possible future careers.

Students participate in the program in three ways. One scenario is classroom-based, with on-site and virtual teachers leading students through hands-on learning activities assisted by Webinar and Learning Management System (LMS) technology. The second scenario is purely virtual, with all students and teachers interacting through Webinar and LMS technology. The third scenario combines those two methods. A secure Learning Management System (LMS) controls access to speaker recordings and notes, activity guides, videos, learning resources, student portfolios, HIT software, and assessment tools. It also enables automated program and student evaluation with built-in data collection, analytics, and reports.

Guest speakers may be high school teachers, college professors and/or students, and industry professionals. Many high school students have a limited view of how their educational journey may lead to prospective careers. Even students with definite ideas about their future career are likely to have incomplete and unrealistic notions of what it will take to realize that career. In **Best We Can Be**, speakers at various stages in their careers (entry-level, experienced, managerial, near retirement) and college (undergraduate, graduate, post-graduate) are invited to make presentations. Speakers talk about their personal experiences and challenges, and rewards of their chosen life path. The Webinar forum provides a secure and convenient platform for students to interact with a variety of speakers. Featured guests include:

- John Moustakakis, Senior Vice President of Information Systems at Westchester Medical Center, describes the challenges of keeping the lights on in the aftermath of Hurricane Sandy, with patients in intensive care tethered and dependent upon HIT to maintain their life functions.
- Dr. Aaron Kershenbaum, a noted pioneer of Internet and networking technology, Visiting Scholar at University of Pennsylvania's Center for Clinical Epidemiology and Biostatistics, and professor of computer science, explains computer algorithms and how interdisciplinary medical teams use them to discover cures for cancer.
- Cindy Robinson, a partner at Tremont Sheldon Robinson Mahoney, widely regarded as one of the best personal injury lawyers in the country, talks about the road that led her to law school, and her job as an attorney specializing in medical malpractice and personal injury cases.
- Xin Tian, a student at the University of Minnesota law school and graduate of New York University's Master of Science program in biology, explores bioethics, and how the legal requirements for animal research in China and the United States reflect different perspectives.

- Robert Suss, a psychology graduate from Stony Brook University, uses online medical imaging software to teach students basic anatomy, and explains how it is used to identify structural anomalies, such as brain lesions associated with multiple sclerosis.
- Liza Salloum, a biochemistry graduate from New York University who will soon be starting medical school, takes students through the HIPAA (Health Insurance Portability and Accountability Act) cyber-security safeguards and how they are implemented in electronic health records (EHR) systems.
- Aditya Tarigoppula, a biomedical engineering Ph.D. student at the SUNY Downstate Medical Center, demonstrates his work designing brain implants that enable control of robotic devices using thoughts alone. This will help paralyzed people live more independent lives.

Best We Can Be's focus on HIT allows students to explore many interdisciplinary connections: medicine and other healthcare careers; computer science (such as cybersecurity, user-interface design, and data analytics); project management; health-related legal considerations, and much more. As the program has evolved, students have asked for additional learning experiences related to business, entrepreneurship, and personal development (study habits, critical thinking, team work, etc.). The program's emphasis on HIT and STEM topics provides many opportunities to weave in lessons that develop these practical skills.

Guiding Principles

The guiding principles behind the design of course content, and student and program evaluation and assessment, reflect the influence of Anne Sullivan's ideas about teaching [16]: i) passivity does not stimulate interest or mental energy; ii) teaching in accordance with a strict curriculum impedes learning; iii) students who are happily interested in their studies learn quickly and without conscious effort; iv) with repetition and repeated exposure, concepts that aren't understood at first can be learned. These ideas evolved as a consequence of her work with deaf and blind children, and her struggles to help them overcome severe learning handicaps. In the words of her most famous student, Helen Keller, "Any teacher can take a child to the classroom, but not every teacher can make him learn. He will not work joyously unless he feels that liberty is his, whether he is busy or at rest; he must feel the flush of victory and the heart-sinking of disappointment before he takes with a will the tasks distasteful to him and resolves to dance his way bravely through a dull routine of textbooks… 'Knowledge is power.' Rather, knowledge is happiness, because to have knowledge—broad, deep knowledge—is to know true ends from false, and lofty things from low [17]."

Guiding principle #1: Have fun

John Cleese, the English comedian, actor, writer, and film producer, is fond of saying [18], "People learn nothing when they're asleep and very little when they're bored!" **Best We Can Be** teaches serious subject matter, without being too serious about it. To ensure students enjoy their learning experience:

- **Student needs and expectations are given voice.** We ask students to share their learning goals, proficiencies, and interests, and to give frank feedback as often as possible. We use this to determine if their learning experience is enjoyable and productive, and to trigger intervention if it is not. During creation of course materials, considerable effect is directed towards answering the questions, "So what? Why should a student care to learn this?" We aim to create content that is interesting, and personally relevant to students and the real world.
- **We use various types of learning content and activities to keep students engaged.** For example, games might reinforce recall of new vocabulary. Electronic Health Records (EHR) software might show how vocabulary is used in healthcare.
- **Students are active participants.** Students must share what they are doing with other students, and are encouraged to ask questions.
- **Content is presented in digestible units.** Sessions are 20 to 50 minutes, depending on the subject matter and learning objectives. Students are not required to sign up for a lengthy series of sessions. Each self-contained learning unit is designed to complement other sessions, and reinforce awareness of the interconnectedness of STEM disciplines.

Guiding principle #2: Encourage reflection on the learning process and critical thinking

Many students avoid studying subjects they perceive as difficult or unpleasant, such as math. Imaging studies show that when this happens, the pain centers of the brain light up [19]. This can lead students into a vicious cycle of avoidance and procrastination. Procrastination, like addiction, brings temporary escape from tedium, followed by increased feelings of despair, as students fall further behind in their studies. **Best We Can Be** helps students recognize these patterns in themselves and to develop strategies to deal with them. The solution involves redirecting the students' focus onto the *process* of learning, and building good habits (break work into small time units, minimize distractions, avoid illusions of competence, plan personal rewards when milestones

are achieved) [20]. Students who use these techniques are better able to manage stress when confronted with complex, unfamiliar topics. Other strategies used to teach critical thinking skills include:

- **Encourage students to embrace an "I can do it" mindset.** Teachers guide students through lessons and activities that stretch them out of their comfort zone. Hands-on practice teaches the student to persevere, and to build skills and knowledge almost unconsciously. Inevitably, students amaze themselves by learning things they thought were beyond their grasp. This builds their confidence and teaches them how to learn. Students are urged to reflect on Malcom Gladwell's observations about Bill Gates, Wolfgang Amadeus Mozart, Bill Joy, and others. They did not become superstars by sheer talent. They needed practice, at increasing levels of mastery, for at least 10,000 hours [21]. Students should spend hours studying STEM not because they have to, but because they want to be better, even exceptional. Students need to internalize the lesson that the path to true knowledge lies in failing, learning from failure, and moving forward.
- **Help students appreciate that STEM knowledge is essential to being a productive global citizen.** General strategies and rote learning will not solve complex problems—such as creating renewable energy sources, finding cures for disease, eliminating poverty, or planning manned explorations of Mars. Modern-day challenges require domain-specific knowledge, expertise, complex problem-solving strategies, and teamwork. In **Best We Can Be**, we introduce students to psychologist Alexander Luria, who conducted field studies in the 1930s on Russian peasants. Luria documented the profound, deleterious effects of illiteracy on perception, abstraction, logic, and reasoning. He showed that literacy is the foundation for sound decision making, personal awareness, and the ability to ask relevant questions [22]. Students need to realize they need at least basic STEM knowledge to be literate citizens and to perform many 21st century jobs.
- **Emphasize the importance of finding reasonable solutions.** Many people are afraid of mathematics because they are afraid they won't get *the* right answer. Then, they give up on trying to find any answer. Students must realize that few real-world problems have only one right answer. They must also learn to recognize when an answer is ridiculous. If students have an aversion to math or science, they may not stop to think whether an answer makes sense. Rather than telling a student an answer is wrong because it's not exactly the answer the teacher wanted, **Best We Can Be** prods students to check whether their answers are reasonable, and look for ways to make them better. This type of thinking helps students recognize the boundaries of their own knowledge pyramid (see Fig. 1). This puts them in a better position to make decisions and to know when they should seek the advice of experts. Students need to know that they will be much more attractive to employers if they are willing to seek reasonable answers to hard problems, despite the limitations of their knowledge. The problem-solving toolkit students acquire when they study STEM teaches them how to do this.

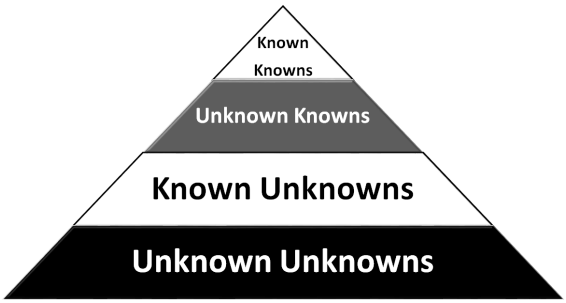

Figure 1. Knowledge Pyramid

Guiding principle #3: Continual improvement requires constant measurement and relevant metrics

Continuous automated student and program evaluation is an integral component of **Best We Can Be**. It is a complex, multi-faceted process, and full explication of the details is beyond the scope of this paper. Major highlights are presented here.

Ideally, program evaluation should be "an unbiased exploration of a program's merits, including its effectiveness, quality, and value" based on reliable and valid evidence of merit [23].

Best We Can Be's content and delivery is personalized, and program participation is self-selecting and voluntary. With this type of program design, the gold standard of statistical evaluation—double-blind, randomized sampling, comparison of treatment and control group outcomes, and hypothesis testing—is not possible. The scope of evaluation is thus limited to participating students, and does not address how they compare to peers who do not participate.

Kirkpatrick's "Four-Level Model for Training Evaluation" is a widely used, time-tested approach that is well suited to training programs such as **Best We Can Be**. It uses four dimensions as the basis for program evaluation [24]:

- Reaction (how participants feel about the training);
- Learning (participants' knowledge, skills, attitudes as a result of the training);

- Behavior (how participants' behavior changes);
- Results (synthesis of all the above data).

To apply Kirkpatrick's model, we ask students to share their reactions to their experiences throughout the program. Students may give anonymous feedback using short online surveys that allow for write-in comments. We measure learning via pre- and post-assessments (with respect to STEM knowledge, skills, interests and attitudes). Measurement of learning also includes students' self-impressions. Learning outcomes are mapped to various standards (e.g., Common Core, etc.) where possible. Behavioral changes are more difficult to assess. Self-reflection surveys completed by students and inputs from mentors work toward this purpose. We see a need for longitudinal studies, to determine whether students remember their lessons and continue STEM-related pursuits as they progress through life. Once students leave the program, it's very difficult to maintain contact and collect follow-up data. We are unable to answer the question, "Why are students leaving STEM majors once they are in college?"

We analyze qualitative feedback, descriptive statistics, significance testing, time series data, and data mining studies of participant and program data to synthesize a holistic view of **Best We Can Be**'s effectiveness, quality, and value. The evaluation process generates useful STEM benchmarks (student performance by grade level, gender, major, etc.), and provides insights for continuous quality improvement. Student feedback is like the behind-the-scenes featurette accompanying a movie. It paints a more realistic picture of the students' learning experience, and is invaluable in shaping our understanding of their needs and motivations. Here are some of the lessons students have taught us:

- Many struggle with time management and have poor study habits that significantly impact their grades and anxiety levels. We created summer workshops to address these topics after students asked for help; however, they were not effective in changing students' habits. Weekly, after-school sessions of about 20 minutes, spread out over three to four months, were needed before students reported noticeable improvements in their study routines.
- Some students struggle with significant life stresses that hinder concentration on their studies (death or illness of a family member; working many hours outside of school; cultural assimilation and difficulties learning English as a second language).
- Compared to students born in the United States, foreign-born students were more likely to report that their families want them to get a job instead of going to college, or that they are expected to pursue a STEM college major to prepare for future jobs.
- Girls planning to study STEM majors in college are worried about whether a glass ceiling in male-dominated fields will impact their future.
- We observe wide variation in skill level across grade levels, with some of the most STEM-proficient students in the lower grades.
- Students like interacting with students in different grade levels—which they would do very little or not at all without the program. They say this interaction enhances their sense of belonging and enjoyment of school culture.
- Even students who struggle academically demonstrate improvement in their STEM skills. Students who have trouble remembering, articulating, or applying STEM lessons they learned in the classroom find it is easier to do so after participating in **Best We Can Be**.

Overall, the experience has a positive impact on students' growth with respect to overall STEM literacy; interpersonal communication skills; self-awareness; planning of life goals; engagement in learning activities; strategies for navigating school and life challenges; and appreciation for how regular coursework relates to their future college and career opportunities. These factors are scientifically linked to academic success and productive learning [25]-[26].

A Customer Relationship Management (CRM) perspective complements the Kirkpatrick evaluation process. In other words, we collect data to capture the essence of the students' learning experience, and how they are responding to it. We use the data to identify personal wants/interests and to aggregate this knowledge into clusters of similar/dissimilar students. Thus, we test and refine communication messages and learning strategies for different student clusters [31]. The data also provide a means to recognize and quantify impacts of problems that arise.

In her book, *Evil Genes*, Barbara Oakley describes how nasty, controlling, tenured teachers can complicate the lives of students and other faculty [27]. These personality types do exist in academia—almost everyone has experienced them to some degree or another. One may rationalize the experience, and chalk it up to "learning a life lesson." However, these encounters may result in a lifelong choice not to pursue STEM. Ebony McGee describes the pained sentiments of minority students who believe they will always be viewed through the lens of negative stereotypes, no matter how well they do or how hard they try. She discusses how difficult it is to capture these perceptions in a scientific, quantifiable way that allows for meaningful discourse and intervention [28]-[29]. CRM helps address this need, too.

Summary and Conclusions

The factors associated with successful STEM educational initiatives are well known [25], [26], [31]. They include: i) knowledgeable and caring teachers; ii) professional development training and mentoring for teachers to build their pedagogical skills; iii) active learning culture that engages students, school staff, parents, and community leaders; iv) respect for diversity; iv) students empowered by a growth mindset; v) access to appropriate educational facilities and resources, including Internet connectivity and computers; vi) and timely, relevant measurement.

The real challenge lies in trying to fix problems when the key success factors are not in place. Bureaucracy guarantees that change will not come easily, despite the best efforts of dedicated, qualified people working to solve the problems. Schools struggle with tight budgets, administrative and technology staff turnover, limited technology resources, competing interests, and intense pressure to prepare students for standardized tests (Common Core standards, SAT, etc.). Tasked with these burdens and responsibilities, schools can't make radical changes, even if they want to.

The emphasis on standardized testing yields few returns and hinders educational initiatives in other areas. We see increasing panic and frustration among administrators, teachers and students as they struggle to adapt to changing standards and tests. President Obama has spoken publicly on this matter: "I hear from parents who rightly worry about too much testing, and from teachers who feel so much pressure to teach to a test that it takes the joy out of teaching and learning both for them and for the students [30]." Learning how to do well on tests has become more important than learning how to learn, and students aren't doing very well in either case. When test time comes, students plead, "Just tell me what to do and what I need to know for the test." This is not increasing the capacity of students to think critically and use their imagination. This type of testing should be discouraged. In his book, *The Predictable Failure of Educational Reform*, child psychologist Seymour Sarason writes about the problems of high-stakes testing. Test scores may point to problems with student achievement, but they do little to help effect a solution [31]. School-level report cards display colorful bar charts ranking students according to racial, ethnic, gender, and socioeconomic categories. These categories relate to inherently personal characteristics the student is powerless to change. The school report card is not actionable, and reinforces negative stereotypes for underperforming groups, without proving any causal relationship or providing prescriptive solutions. Tests can play an important role in learning, but too often they are used to justify assigning a label to the student or to "weed them out." If too many students pass a test with flying colors, the cutoff for a "good" score will likely be adjusted upwards according to an arbitrary formula. SAT and other standardized test scores are like the dollar: how they are used determines their value; when they are not used for their intended purpose, they are meaningless. **Best We Can Be** uses tests to reinforce learning and recall. The goal is for every student to receive a perfect score—indicating mastery of the subject matter—and not to determine the student's rank order relative to peers.

Schools and states are investing heavily in systems to collect data on students as they progress through K-12 and beyond. The data collection includes test scores, attendance, learning disabilities, hobbies, career goals, attitudes toward school, family wealth indicators, expulsions and other disciplinary actions, teen pregnancy information, mental health history, criminal history, medical test results, birth order, parental education, transcript information, college readiness test scores, and more [32]. The potential for abuse of student information is enormous; the link between all this data collection and improved educational practice is tenuous at best. Data needed for unbiased program evaluation are not collected, although schools collect volumes of data of questionable relevance, without a plan or the tools to use it appropriately.

Best We Can Be is an online, extracurricular program not bound by the same restrictions that apply to in-school programs. Even so, it is not easy to work with schools. We are working to forge relationships with community groups and non-profits that support STEM educational initiatives. We have thus gained greater appreciation of the sheer multitude and diversity of excellent STEM programs, and understanding of how hard it is to keep them going. These programs are isolated victories, and do not suffice to re-engineer education. For this, secure funding sources, a sustainable base of support, and tools for collaboration and mutual support are all needed.

Looking back, **Best We Can Be** met the goals established by AITE. It demonstrated that online instruction can foster student interest in STEM and help close achievement gaps by accommodating diverse populations and maturity rates. It supports programs for at-risk students while providing avenues for gifted students to engage in personalized learning. **Best We Can Be** collects student data via a secure online LMS system, to support program evaluation based on Kirkpatrick's model for training evaluation.

Looking forward, the authors are mapping educational ontologies and related semantic categorical labels to collected data. The goal is to create a dictionary of universal metrics and a common basis to make comparisons across diverse student populations and STEM training programs. Universal metrics provide contextual information (relating to assessment

questions, assessment domains, STEM program information, student characteristics, and teacher characteristics) enabling apples-to-apples comparisons. As an example, contextual information for a math assessment question might include reference to the associated Common Core standard (e.g., 9-12.HSN-VM.A "Represent and model with vector quantities").

Calls for educational reform and revolutionary approaches to teaching STEM have been on-going for decades. In response, we have recently seen an explosion of new STEM programs within and outside traditional school structures.

But as more STEM programs are developed, competition for funds and students' attention increases as well. Better yardsticks will enable more informed choices. Evaluating program impacts and quality, and making comparisons with other approaches, are complex tasks. They require universal metrics and data collection that enable a consistent and holistic perspective across all programs. Evaluation should explicitly consider the context of the students' learning experience, and the quality, value, and effectiveness of the STEM program. The right questions must be asked, and the right data collected, before we can develop and implement plans to reform STEM education. Perhaps revolution should not be the goal. As history has shown, the desired state seldom emerges quickly or with certainty from revolution. Measurement of relevant data provides a basis for steady improvement and evolution.

Ultimately, evaluation and assessment of STEM teaching programs contributes to greater overall realization of the complexities and interdependences that manifest as learning cultures. This understanding is necessary to the creation of a workforce with the STEM skills needed to succeed in today's society.

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