Developing an Interdisciplinary Healthcare Improvement Workforce

Dr. James Benneyan, Northeastern University

Dr. James Benneyan is former senior systems engineer at Harvard Community Health Plan and founding director of the Healthcare Systems Engineering Institute at Northeastern University, including three NSF and CMS funded centers and five undergraduate through post-doctoral degree, internship, and fellowship programs. Jim is faculty and senior fellow at the Institute for Healthcare Improvement, holds joint appointments in Northeastern's engineering and health sciences colleges, and past is President of the Society for Health Systems. He serves on numerous editorial and advisory boards, has received 12 research, teaching, and service awards, and has been principal investigator or co-director in seven research centers totaling over $32 million in funding.

Mr. Corey Balint, Healthcare Systems Engineering Institute at Northeastern University

Corey Balint, holds both a BS and MS in Industrial Engineering from Northeastern University and currently is a staff healthcare system engineer in the HSyE institute. Current responsibilities include: serving as day-to-day project manager of our AHRQ patient safety center, leading a portfolio of roughly 10 projects at any time, and assisting with senior team projects. Balint has expertise in quality, medical staff services, change management, Lean, Six Sigma, and other performance improvement methodologies and has extensive experience working with numerous healthcare organizations and culture.

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Introduction

From the co-chairs of the President's Council of Advisors on Science and Technology (PCAST), John Holdren and Eric Lander, June 2014[1]:

> *"We are pleased to send you this report by your Council of Advisors on Science and Technology, Better Health Care and Lower Costs: Accelerating Improvement through Systems Engineering. This report comes at a critical time for the United States. Health-care costs now approach a fifth of the U.S. economy, yet a significant portion of those costs is reportedly "unnecessary" and does not lead to better health or quality of care. Millions more Americans now have health insurance and therefore access to the health care system as a result of the Affordable Care Act (ACA). With expanded access placing greater demands on the health-care system, strategic measures must be taken not only to increase efficiency, but also to improve the quality and affordability of care."*

This report to President Obama recommends that, aggressive mechanisms must be developed in order to rapidly increase the visibility and application, of systems engineering in healthcare and in tandem increase the demand for an experienced workforce. As healthcare begins to transition towards modernized systems engineering methods that are used in manufacturing and in agriculture, academic and applied programs are necessary in order to fulfill the demand. This paper describes an experiential learning program which trains students in the methods and applications of healthcare systems engineering. Additionally this paper will verify that the programs under this model are scalable and are easily replicated nationwide.

Background

History of Industrial and Systems Engineering (ISyE) in Healthcare

Although ISyE was lauded in the 2014 PCAST report, engineers worked for many decades to improve the healthcare system and establish a long term partnership with healthcare providers. In the 1980's Donald Berwick, former President and CEO of the Institute for Healthcare Improvement (IHI), espoused that continuous improvement is a necessary solution to the ongoing problems in healthcare [2]. During that decade, healthcare professionals observed an increasing amount of inefficiencies in the system which reinforced complexity and contributed to increasing costs. Two methods of improvement dominated the healthcare industry: 1) inspection and correction of problems and 2) continuous improvement. Inspection, as Berwick described, is the "Theory of Bad Apples" meaning "quality is best achieved by discovering bad apples and removing them from the lot." Berwick disagreed with this theory:

"We are wasting our time with the Theory of Bad Apples and our defensive response to it in health care today, and we can best begin by freeing ourselves from the fear, accusation, defensiveness, and naiveté of an empty search for improvement through inspection and discipline. The Theory of Continuous Improvement proved better in Japan; it is proving itself again in American industries willing to embrace it, and it holds some badly needed answers for American health care."

Manufacturing industries in Japan have been using the Continuous Improvement mentality in their production for decades. Much of the work we as systems engineers do, has been vastly influenced by Toyota and "The Toyota Way"[4]. We now need to take that mentality from the manufacturing floor and put it on the hospital floor.

Affiliation and Funding

Directed by MIE faculty James Benneyan, the Healthcare Systems Engineering Institute (HSyE) is a university-wide institute focused on broadly impacting healthcare through the integration of research, application, and education in systems engineering methods. The HSyE Institute houses 3 federally-awarded healthcare IE centers, coop and summer internship programs, and a post-doctoral development program, with $27 million to-date in funding from the National Science Foundation, Center for Medicare and Medicaid, National Institutes for Health, Veterans Health Administration, and Agency for Healthcare Research and Quality.

Supported by a new $8 million Health Care Innovation Award (HCIA) from the CMS Center for Medicare and Medicaid Innovation, HSEC's mission is to develop a scalable regional healthcare systems engineering extension center that measurably impacts the "triple aim" of better care, better health, and lower costs through application and workforce development in healthcare systems engineering. Led by Principal Investigator Dr. James Benneyan, the HCIA grant funds the first phase of a 10-year project to establish a national network of healthcare systems engineering regional extension centers across the U.S. The overall goal is to demonstrate the potential impact and viability of replicating this initiative on a national scale, to-date conducting projects with projected $24.5m 3-year savings.

Structure of Center

External

The Healthcare System Engineering Institute operates out of Northeastern University in Boston. Both center and university have a significant joint interest in applying academic research to the common issues in various industries and developing solutions that are applied in diverse settings, including hospitals, labs, or a manufacturing plant. Northeastern has also developed a world class placement program that attracts a flourishing pipeline of students who learn valuable skills by working in a number of industries. Being located in Boston has helped

develop the program rapidly, as there are many prominent healthcare institutions in close proximity.

Below is the basic structure of the center and its partners. The center unifies the academic and healthcare communities in their problem solving venture and it develops solutions using research and expertise in ISyE methods and implements them in the healthcare industry.

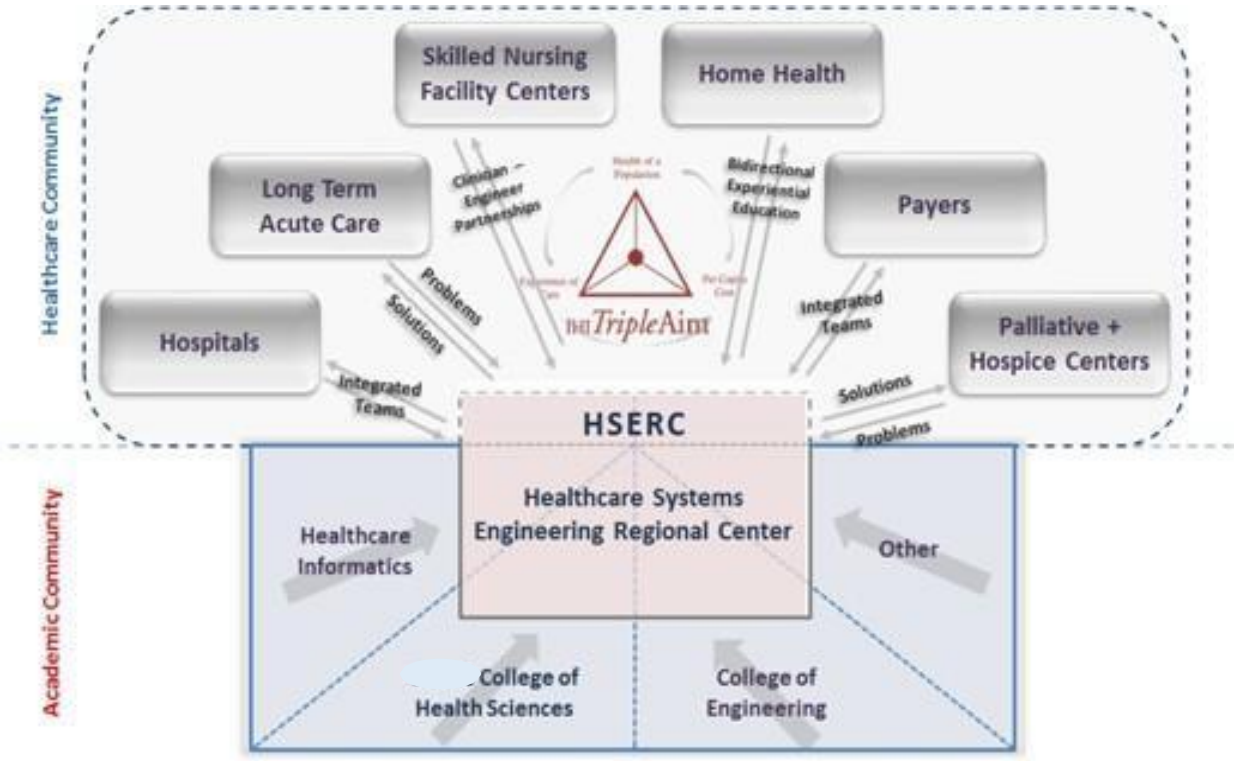


Figure 1. The structure and premise of interactions of the (institute's name).

The institute's work started by developing relationships with the healthcare providers in local hospitals. Staff and students would travel, physically or virtually, to the system to discuss ongoing problems. Staff and students, from both the center and hospital, are paired together to come up with implementable solutions. This project method allows for ISyEs to develop a stronger knowledge of healthcare and its problems, while also allowing for the healthcare employee to develop a stronger understanding of ISyE methods and relevant applications for it.

The importance of integrating ISyE with healthcare providers cannot be overstated. When projects are completed, healthcare providers receive insight into the complexities of their hospital and begin to observe a correlation of systematic issues in similar forms. Internally, the healthcare system can apply the information and toolsets that were provided in order to sustain the improvement and to focus on similar issues in the hospital. The benefit, whether it be focused on cost, care, or health, becomes exponential.

Most important, the students observe the functions of a health system or hospital in real time and explore the trends that contribute to higher costs, ineffective care, and inefficient processes. Upon their graduation from the program, they have skills and expertise to bring elsewhere. Consequently, we achieve several of our goals for the grant of spreading awareness of ISyE methods and creating an experienced workforce

While work was centrally focused on the hospitals within the home city, projects have expanded to a diverse group of healthcare centers in approximately seven cities. Below is a table of health systems that were our partners throughout the grant. The various types of systems allow for the center to develop and test robust solutions to common problems like hospital acquired infections and readmissions.

Boston / New England (19/23)		**Seattle (4/7)**	**Charlotte (1/4)**
Baystate Medical Center	Maine Health	Evergreen	Carolinas Health System
Beth Israel Deaconess Med Cnt	Maine Medical Center	Harborview Medical Center	*Hospice & Palliative Charlotte*
Boston Children's Hospital	Mass General Hospital	*Providence Health System*	*Novant Health*
Boston Medical Center	MidCoast Maine	*Seattle Cancer Care Alliance*	*Premier*
Brigham & Women's Hospital	*Mount Auburn Community IPA*	Seattle Children's Hospital	
Cambridge Health Alliance	Southcoast Hospital (NEQCA)	*Swedish Health*	**Denver (0/2)**
Commonwealth Care Alliance	*Southern Maine Health*	Virginia Mason Medical Center	*Colorado Childrens*
Dana Farber Cancer Institute	Tufts Medical Center		*Kaiser Permanente*
Hallmark Health System	*UMass Memorial*	**Elsewhere (2/2)**	
Harvard Vanguard Med Associates		Moffit Cancer Center (Tampa)	**San Francisco (0/2)**
Lahey Health System		MDACC Cancer Ctr (Houston)	*Contra Costa*
Logix Health		Mary Washington Hospital (Balitmore)	*Kaiser Permanente*
Lynn Health Center		*Centrastate Medical Center (NJ)*	Doctor's Medical Center Modesto

Figure 2. Locations of partnering health systems.

Figure 3. Map view of partnering health systems

Internal

The key structure of the workforce is composed of graduate students, undergraduate coops or interns, and post-doc mentors who work in teams with faculty, medical professionals, and hospital administrators. These teams work together during the six to nine month project lifecycles, each member having slightly different roles. As an example, one team in the center is the following: staff engineer trained in ISyE, graduate student with an economics degree, an undergraduate biomedical engineer, and a staff member with a communications degree. The staff member helps with project management, the staff engineer leads the team technically, the graduate student develops the tools needed, and the undergraduate students gather data and help test the tool. Many of these students, especially our interns and co-ops, work on their projects remotely after they return to their university of origin.

The Healthcare Systems Engineering institute is an academically founded program. The academic mentality resonates through the entire structure of the program and all of the work that is done as each team working on a project is from a multidisciplinary background. The workforce is comprised of an assortment of employees: professors, graduate students (co-ops, interns, research assistants), undergraduate students (co-ops, interns, part-time students, work studies, research assistants, capstone, independent studies), engineers (MS and BS in ISyE), physicians (we call them ‘clinicians in residence’), and an assortment of other staff (administrative, reporting, communications and events). The academic background of the center is very diverse, ranging from ISyEs and biomedical engineers to MD students and retired clinicians.

While students are working on more than one project at a time, they are able to see different types of healthcare systems and problems. The employees within each system have vast differences as well, each of which have their own way of approaching and solving problems. While doctors and nurses may need to keep more of a focus on the individual patients, data analysts and MHAs may need to have a greater focus on what is going on at the whole system level. These two distinct methods of thought help students develop a greater appreciation and knowledge of decision making.

Involvement in the Program

As mentioned above there are numerous facets within the center that engender student participation. These methods include: summer internships, co-ops, research, independent studies, and capstone projects. At our center, experiential education is divided into two programs: summer internship and co-ops. The summer internship program includes spring preparation, a summer cohort experience working on several applied and research problems, and fall reflection and dissemination activities. The co-op program includes full six month immersion into an academic center focused on application of researched problems. In the summer of 2014, the center had 10 undergraduate co-ops, 26 interns (out of 250+ applicants), and 19 graduate students actively working on projects, each with typically 2-4 projects per student.

The center also participates in the formal educational model. Students can reach out to work on independent studies and research projects. They vary greatly depending upon the interest of the student, but they all fall within healthcare improvement. The center also runs capstone/senior design projects which are intended to reflect what students have learned through coursework and any other experiential education, by giving them an open ended problem and allowing them to solve it. Students receive a grade for their work in the capstone program, with projects that are shorter in duration for the purpose of easier and faster implementation.

Below, in Table 1, is a description of some of the most common problems we have worked on. These problems now all have a standard approach that we have implemented for ease of students and healthcare workers. The ability to port solutions from system to system saves hundreds of hours of work for all involved.

Emerging high impact areas	Focus	Approach(es)
1. Optimizing triage of specialty referrals to most effective and efficient provider and method	Reduce costs, access, satisfaction	Predictive modeling, statistical analysis, process design, criteria optimization
2. Over-use ED imaging, related diagnostics	Unnecessary utilization, associated costs	Dashboard development, variance reduction, and reliability science
3. Resource utilization predictive modeling and corresponding load leveling	Improve flow, reduce costs	Simulation models, adaptive resource optimization programs
4. Patient safety	Reduce harm, associated costs	Statistical quality control, reliability engineering, human factors
5. Pediatric and neonatal wellness	Reduce costs, improve health starts. Leverage	Process analysis, statistical quality control, PDSA testing
6. Macro system planning and capacity optimization	Costs, over/under capacity, equitable access	Optimization and simulation models, statistical analysis

Table 1: Emerging common project focus topics.

Results

One of the center's major aims was to track the number of employees, both internal and external, that have been trained in ISyE or healthcare methods. The figures below show the progress on the goals.

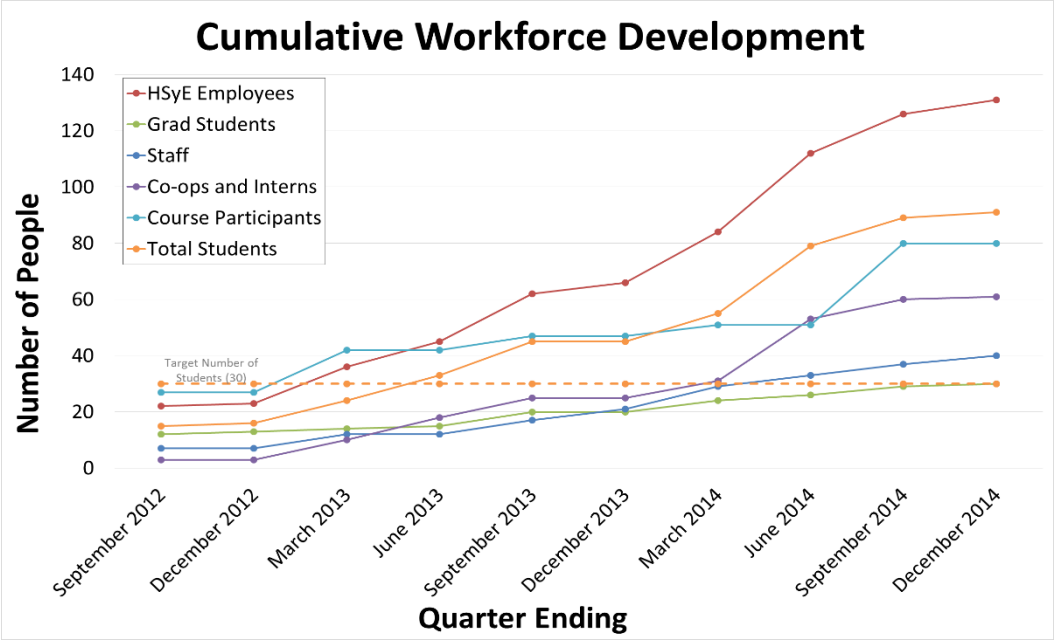


Figure 4. Workforce directly developed through the center. The student goal has already been exceeded before the end of the grant by more than three times the amount planned for.

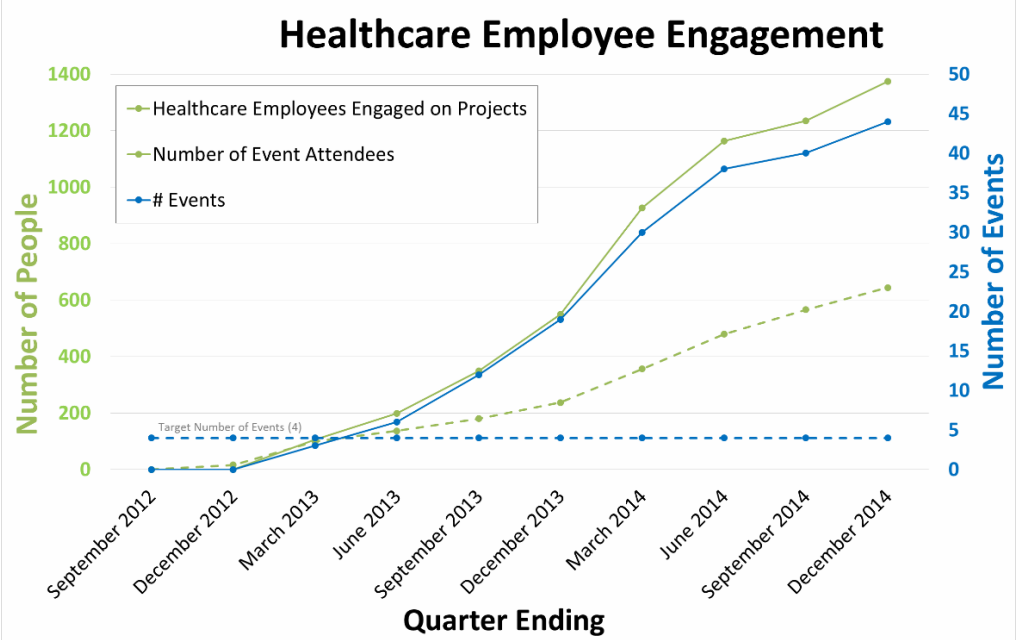


Figure 5. Healthcare employees engaged with (taught ISyE methods) during the course of the grant. Our reach, again, has far exceeded our expectations.

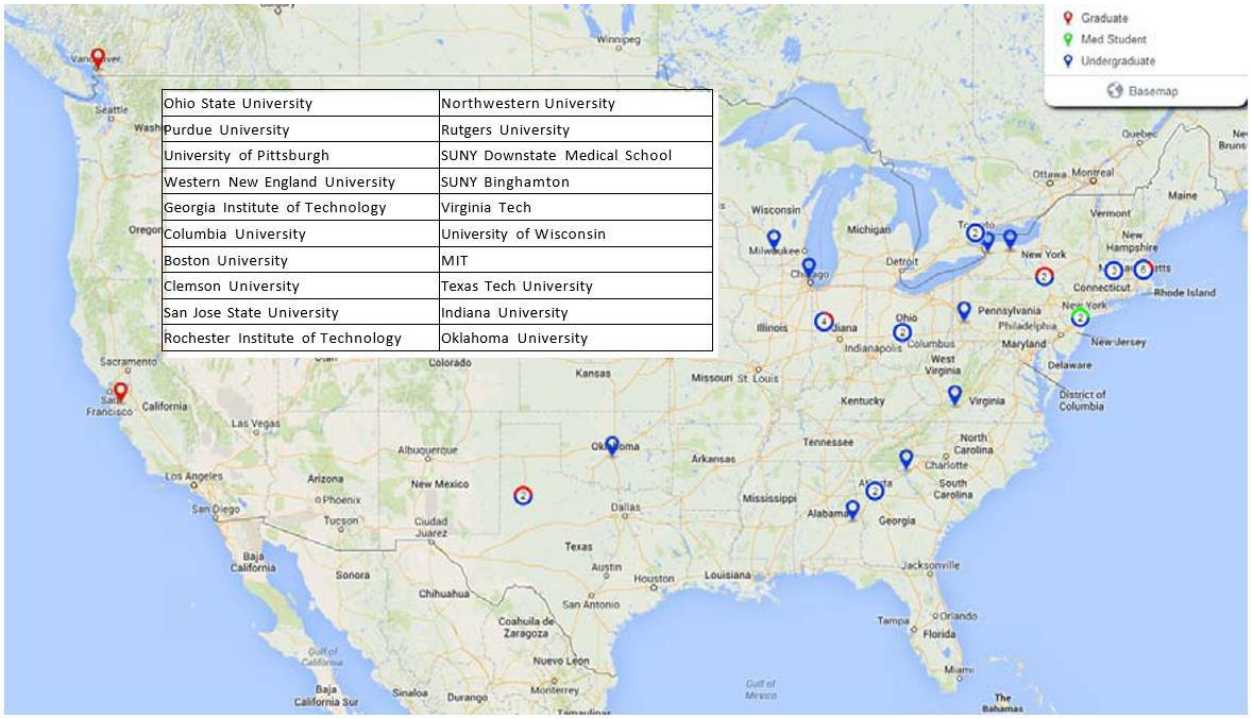
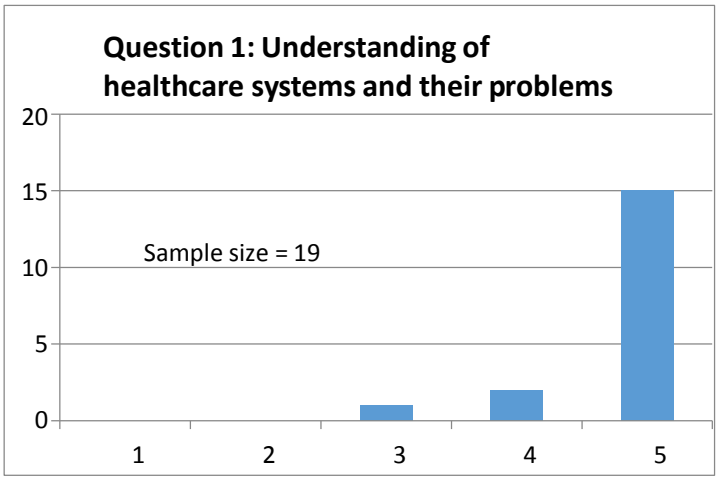
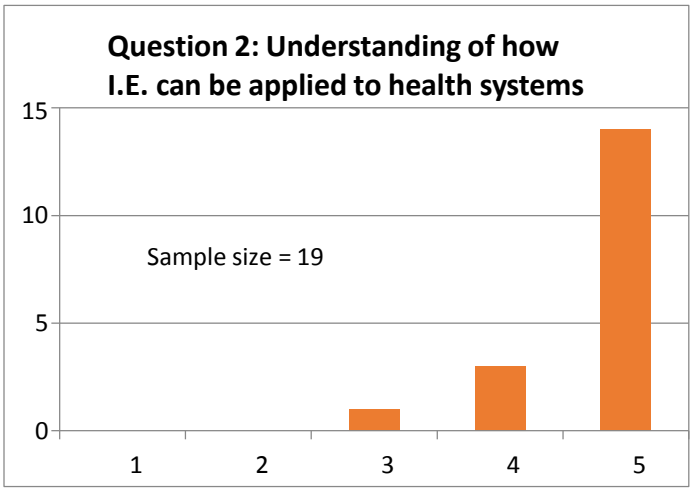


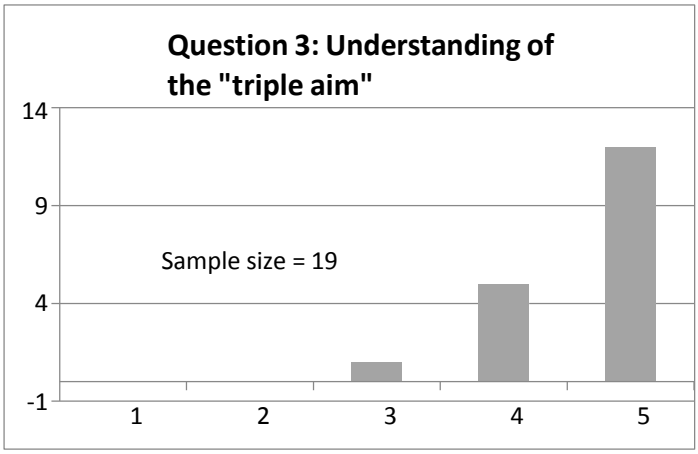
Figure 6. Map of the home institute of our former summer interns (blurred for review). The draw of the program has now seen students from fourteen different states and twenty different universities come through our doors.

Since inception of the Healthcare Systems Engineering Institute		Over the duration of the award	
Name	**Placement**	**Name**	**Placement**
Erkhan Ceyhan (PhD)	Lahey Health	Alessandra Snigur	HSYE Staff engineer
Jordan Peck	Maine Health	Ronit Patnaik	IU School of Medicine
Natasha Taylor	UMass Memorial	Debashree Sengupta	SUNY Downstate College of Medicine
Claire Bond	UMass Memorial	Natalie Souther	Premier Inc.
Bonnie Baker	Martin's Point Health Care	Amanda Bell	U or Toronto Healthcare Systems Engineering
Sam Ruokis	University of Chicago Medicine	Kelli Crosby	Pitt VA
Kim Eng	BIDMC	Melissa Marinace	Johns Hopkins University APL Healthcare
		Tom Abreu	Beacon Health Strategies
Over the duration of the award		Sabrina Tang	U or Toronto Healthcare Systems Engineering
		Ellen Wilson	Booz Allen Hamilton
Name	**Placement**	Cory Stasko	MIT IE student, HSyE Research fellow
Luke Romeo	Long Island Jewish Medical Center	Ally McCall	Healthcare Consulting
Rachel Miller	Hill Physician's Medical Group		
Nick Andrianas	Johns Hopkins University APL Healthcare		
Onur Uzunlar	Sandoz		
Laura Hyde	Athena Health		
Hande Musdal	Northeastern Post-doc		
Dayna Martinez	Northeastern Faculty		
Corey Balint	NU HSyE Staff Engineer		
Salah Haridy	Academia		
Kendall Sanderson	HSyE grad student		

Figure 7. Former students/employees who have moved onto careers in healthcare. In a few short years, the center has helped students bridge the gap from academia to industry.







Figures 8-10. Student assessment from the 2014 Summer Internship program, where 1 is “No understanding” and 5 is “Great understanding.” A majority of students are now far more prepared to seek employment in healthcare. Additionally, “the IHI Triple

Aim is a framework developed by the Institute for Healthcare Improvement that describes an approach to optimizing health system performance. It is IHI's belief that new designs must be developed to simultaneously pursue three dimensions, which we call the "Triple Aim"" [5] The Triple Aim is used as the measures of success for improvement projects in healthcare.

Conclusion

Over the past two years, participants included 109 industrial engineering, human factors, MPH, bioengineering, statistics, and medical students from 14 states and 4 countries, most working in healthcare for their first time. Evaluations of the program by student and health system participants have been very positive, including experience working with health systems, learning how IE applies to health care, academic advising and career support, and opportunities to build technical, communication, and teamwork skills. All participants summarize their experiences, what they gained from the program, and how it has affected their career and academic directions.

Programs like this need to be developed and nurtured quickly. As Gary Kaplan, et al stated "...[systems engineering] approaches remain generally underutilized in the health system, and their potential for improvement remains largely untapped."[6] The ability for students to have interactive experiences in an interdisciplinary field will help foster an understanding of the problems on both a large and small scale. This should only motivate more students to go into this field. If these students can be exposed to ISyE in a healthcare setting our national issues may become our strengths.

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Appendix

Below we have two sets of tables from our 2014 Summer Internship Program. The first is a summary of skills and experiences the interns reported to have gained in their time here. The latter is a table of qualitative responses after their time in the center.

Summary of skills and experience gained in 2014 Summer Internship Program

Skill/Experience Area	Frequency of responses noted
Technical skills	19
Understand US Healthcare (policy, first-hand experiences)	17
ISyE applications to Healthcare	15
Multidisciplinary work, working with Healthcare personnel	11
Communication	11
Interest in continuing work in Healthcare	9
Gained friendships	9
Difficulty implementing projects, other challenges in Healthcare	9
Triple Aim	7
Teamwork	6
Data analysis	5
Diversity	5
Presentation skills	3
Project management	3
Change management	3
Data collection	3
Research applications	3
Leadership	2
Interest in Graduate school	2
Technical writing	1
Running efficient meetings	1
Work styles - could apply to multiple above	1

Participant Growth & Impact Representative Statements

"I have learned so much about the healthcare system and how it operates. I learned about communication and working with hospital personnel. I also learned a lot of technical skills, such as pivot tables and Visual Basic."
"I learned about various applications of industrial engineering in healthcare and started to grasp the issues. I developed project leadership skills, learned about change management. I learned about the value of working with groups of people from diverse backgrounds, and gained many important and lifelong connections/friends. I solidified my interest in working healthcare, and developed a more defined plan for my future through interviews with professionals in the field."

"I gained more knowledge in healthcare and use of Industrial Engineering tools, including simulation and Arena. I gained better communication and presentation skills. Mentoring, In-Services, and IHI Open School are very useful."
"This program was a great introduction to the use of IE tools in healthcare! I learned effective communications methods (teamwork internally and with collaborators at health systems), background on health policy, and insight on the flaws of the current US healthcare system. With no previous exposure to IE techniques, I not only learned technical methods, but I also discovered a new way of thinking. I made many valuable connections and learned to fully appreciate diverse teams."
"As a medical student, this was an eye-opening experience for me. I had the chance to learn how to mesh the medical world's focus on the individual patient with a systems level look at healthcare. I enjoyed the exposure to engineering principles. Undoubtedly, I will come back to these principles in my career, and I look forward to working with systems engineers again."
"Compared to last year, I learned much more of the technical tools behind healthcare systems engineering, particularly when it comes to simulation."
"I learned a lot about the current state of the US healthcare system and how industrial engineering-related applications are being used to help improve healthcare delivery. Coming from a biomedical engineering background, I learned a lot about IE techniques themselves, and how greatly they can impact healthcare. I also learned that, even if a change to a system seems simple conduct, it could take a long time to implement at a health system, especially if it's a large hospital network. It's important to get hospital staff feedback, otherwise a new process may not be sustainable. This experience was a positive one for me, and it has confirmed my continued interest in working in process improvement in healthcare."
"Throughout this internship, I learned how important and valuable interdisciplinary teams are. Working with different people from different universities, different points in academic career, and different majors has definitely been an eye-opening and insightful experience. I learned that as engineers, not only are technical skills valuable, but the communication of what we know to non-engineers are even more significant in the success and progress of projects. I'm also glad that I got exposed to a lot more of how healthcare systems work in first-hand and just how difficult it is to implement triple aim is in projects but also how important it is to be mindful and strive towards it as well. While I still consider myself an amateur, I was glad that I got a chance to improve my MATLAB skills and was reminded again how important coding/programming was for engineers and intend to take a course on MATLAB. I've learned that there are many ways to improve health systems and impact and make a difference without high level academic background. I also was able to learn that not all data is useful and how important it is to plan ahead of time on what types of data to be collecting and how to analyze data without falling into the temptation of shaping the results of what we want it to be."
"This summer has been a great experience for me in multiple ways. First of all, I got to explore the beautiful city of Boston and make new friends. I got to have hands on experience in a hospital that I have been seeking and it was very educational. While CHA did take up a lot of my summer, the things I learned through the project were very beneficial. It gave me a chance to make large gains in my interpersonal skills in a workplace environment. I enjoyed being the "lead" of part of a project; it made me feel like I was actively making a difference. I also added to my technological skills in a major way – Excel VBA, Python, and Process Simulator were all programs that I got to spend time learning. IHI Open School was also an

enlightening experience and very interesting. The biggest takeaway I received from this program was simply learning about a healthcare systems engineer's experience. I came into this summer hoping it would help me decide which direction to go after graduation. I'm still a little uncertain, but I received kind mentoring on both how to continue in the healthcare systems engineering field, and how to pursue my other interest field of rehabilitation engineering. I hope to apply to some healthcare systems consulting companies in the fall/spring. This program greatly benefited me in that way; I feel confident that I can speak about my experience and be a competitive applicant. This internship helped me determine a post-graduation plan and I am so grateful for that."
"This internship pushed me to look at the bigger picture in healthcare systems. I learned the importance of clear and goal based communication, with healthcare professionals. They understand the system while Engineers can narrow down a problem, define the scope and open up new avenues of thought for healthcare professionals. This is why collaborations between them is essential for improvements in our healthcare systems. I've learned that hospitals are slow to change and have also learned quite a bit about how the American health system is organized (especially through in-services). As I continue my career as a medical student, I hope to look at the bigger picture of health systems so that our patients don't fall through the cracks – so they receive the care they deserve. This internship has solidified my view that healthcare is a right and it is possible to make that a reality in the U.S."
"The summer internship gave me a lot of opportunities to learn engineering applications in healthcare and also how healthcare systems run today and how much we can improve it. I expanded my knowledge in an umbrella of concepts, and not only in engineering ones. I know a lot more about the triple aim, patient safety, and process improvement, and how to communicate better with non-engineering people. I feel that this opportunity expanded my knowledge not only in healthcare, but also in how to apply engineering tools and concepts to any real problem. I can also say that now I have a different mindset to approach problems and this experience will be a big differential for my career when I go back to Brazil."