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FOOT in the DOOR

Industrial systems engineering steps into healthcare to improve quality, cut costs, and save lives.

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By noting and fixing inefficiencies, systems engineers – researchers and students – are out to show they can make medical practice cheaper while improving quality.

By Mary Lord

DESIGN BY NICOLA NITTOLI

With their lab coats and hospital badges, the 20-somethings pacing a trauma unit in California's Santa Clara Valley could easily be mistaken for medical residents. Though driven by the emergency-room dictum that every minute counts in saving a life, these aren't physicians in training. They're engineering undergraduates analyzing the movement of practitioners between supply shelves and patient, with the goal of reorganizing the room to shorten the route and hasten treatment. They're also early recruits in an ambitious effort by a few pioneering engineering schools to deploy a new class of medical professionals across the country – one that uses industrial and systems engineering to enhance clinical care while lowering costs.

Can tools designed to improve manufacturing processes help diagnose and remedy inefficiencies that harm quality and hike costs in a system as complex as healthcare? James Benneyan, a professor of industrial engineering and operations research at Northeastern University, has proof. Participants in his rapidly expanding program of internships, co-ops, research partnerships, and demonstration projects are collaborating with frontline clinicians to solve such actual problems as locating a bottleneck in the discharge of heart patients, managing bed demand, reducing blood-bank waste, and boosting the breastfeeding of preemies in intensive care units across Massachusetts. Such applied research not only promises to benefit patients, but also to strengthen the pathway between engineering schools and an industry that consumes 17.4 percent of the nation's GDP.

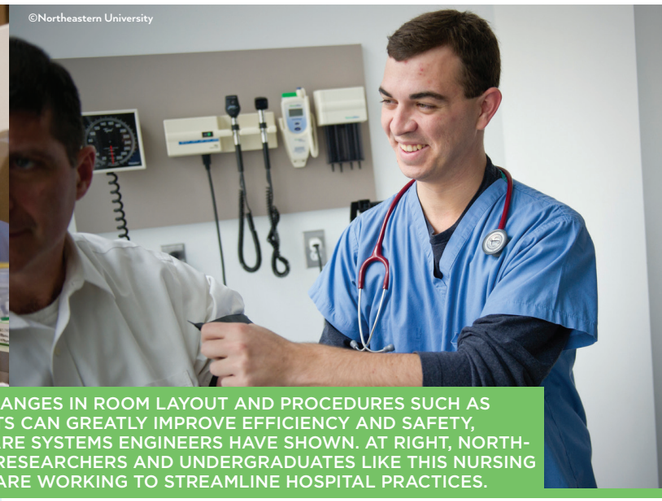
"We're teaching them how to be engineers, we're teaching them about healthcare, and we're teaching them how to do it in the real world, where we need an 80 percent solution now, not a perfect solution next year," says Benneyan, a former senior systems engineer at Harvard Community Health Plan and founding director of Northeastern's Healthcare Systems Engineering (HSyE) Institute, an educational leader in introducing industrial concepts to healthcare.

$1 TRILLION IN 'PURE WASTE'

When the National Academy of Engineering listed improving medicines and healthcare informatics among the century's "grand challenges," its lofty focus was on personalized medicine – not emergency-room workflows or bed turnaround times. But with Americans now spending roughly $3 trillion a year on healthcare – a third of it "pure waste," Benneyan calculates – and annual hospital admissions topping 35 million, even small improvements can yield systemwide payoffs. In one case study presented to Benneyan's HSyE students, for instance, a Tennessee medical center saved more than $111,000 a year by changing the process for supplying clean sheets and blankets to reduce shortfalls that kept patients waiting for beds. As restock orders fell from 55 per day to five, so did complaints. Benneyan contends that 70 percent of healthcare problems can be remedied by reorganizing supply cabinets and other front-line fixes.

Healthcare systems are famously resistant to change, but engineers can make a meaningful difference even with seemingly small adjustments. "The most simple type of fixes often are the most simple to do and sustain," observes Kyle Cunningham, a University of Buffalo engineering graduate now conducting research full-time in the HSyE lab while pursuing a master's degree in operations research. For instance, he says, "a checklist can end up saving millions of dollars." His own team created a standardized "patient hand-off" protocol to ensure that critical information about a patient, such as whether he received his full dose of medicine, does not get lost when nurses change shifts. Physically checking off items, explains Cunningham, "eliminated a little bit of human error" and reassured the nurses.

Such "systems thinking" comes straight from the total quality management playbook of engineer and statistician W. Edwards Deming. Embraced by Japan's war-ravaged industries during the U.S. occupation, it combines statistical methods, workflow modeling, and optimization studies to reduce waste and ramp up quality in manufacturing systems. Deming's basic philosophy holds that by focusing on continual improvement and using data to streamline processes from the major to the mundane, the whole organization runs better. Benneyan aims to prove the approach can similarly benefit the medical world – and not just one hospital. His vision: Use project-based industrial systems engineering education to expand research partnerships, train the workforce, and reconfigure workflows so that solutions can last.



SIMPLE CHANGES IN ROOM LAYOUT AND PROCEDURES SUCH AS CHECKLISTS CAN GREATLY IMPROVE EFFICIENCY AND SAFETY, HEALTHCARE SYSTEMS ENGINEERS HAVE SHOWN. AT RIGHT, NORTHEASTERN RESEARCHERS AND UNDERGRADUATES LIKE THIS NURSING STUDENT ARE WORKING TO STREAMLINE HOSPITAL PRACTICES.

Few dispute that U.S. healthcare requires fresh thinking. A new report by the National Academy of Medicine, formerly the Institute of Medicine, determined that most Americans will get a wrong or late diagnosis with potentially fatal consequences, and called for a systemwide overhaul. The problem could affect as many as 12 million adults annually – far more than the estimated 100,000 deaths caused by hospital errors each year cited by a 1999 Institute of Medicine study. Meanwhile, physicians, hospitals, and the federal government have spent billions preparing for a sweeping revision of procedural terminology that will expand the current list of ailments and treatments from roughly 14,000 today to 68,000.

A growing body of evidence shows that engineers can boost patient safety and cut costs. The President's Council of Advisors on Science and Technology (PCAST) recommended the approach in its 2014 report "Better Health Care and Lower Costs: Accelerating Improvement through Systems Engineering." The report also cited the lack of industrial engineers trained to work in healthcare as one of the biggest barriers. "We shouldn't have to have another meeting about whether industrial engineering can add value to healthcare," says Benneyan, a past vice president of the Society for Health Systems who has served on several Institute of Medicine studies. "We need to create demand, and we need to create the workforce and methodology to scale up and do it nationally."

12 MILLION U.S. ADULTS MAY RECEIVE AN INCORRECT OR LATE DIAGNOSIS THIS YEAR.

HSyE's role in advancing a "research ecosystem," engaging healthcare systems engineers, patient safety experts, and medical centers, has generated interest from the National Academy of Medicine. In September, the Academy hosted a briefing by Benneyan on the institute's progress, including lessons learned from a recently concluded $8 million grant from the federal Centers for Medicare and Medicaid Services (CMS) to create a USDA-style regional extension center demonstrating the value of industrial and systems engineering to healthcare. Benneyan's briefing evidently impressed the attendees, because, he says, discussion quickly turned to ways that Northeastern's work could be replicated across the country.

The rapid growth of Benneyan's program suggests a hunger for innovation throughout the healthcare system. In the past seven months alone, the institute has received $12 million in research grants to do applied work with doctors to reduce waiting time in emergency rooms. Its 72 postdoctoral researchers, graduate students, and undergraduate researchers now have more ongoing projects than they can handle. Besides research, the institute comprises a large co-op program – a Northeastern tradition – and a summer institute that draws biomedical, statistics, and other non-engineering majors from 43 universities in 21 states and four countries. Using just word-of-mouth promotion, this past summer's institute attracted 600 applicants for 24 spots, one of which went to a first-ever high school student.

HSyE has started doing just that. Since receiving a federal innovation grant in 2012, the institute has conducted some 62 projects in more than 40 healthcare systems in 10 states. It reports delivering $24.5 million in savings; significant reductions in unnecessary imaging, referrals, and harm; and the workforce development of 127 industrial engineers and 472 healthcare personnel. Benneyan estimates that nearly 1,400 clinicians have been taught industrial systems engineering methods, and satellite centers are being cultivated in Seattle, Charlotte, and San Francisco. The working relationship has proved so productive that several industry partners have sought the institute's assistance in co-writing innovation grants for such projects as reducing patient falls.

At the core of developing a new generation of healthcare systems engineers is project-based learning, like the trauma unit redesign that two students from San Jose State University did in their capstone course. "Ten percent of everything we do is just bring people together... and then the magic happens," says Benneyan. However, projects must be carefully designed and win over skeptics among frontline clinicians. "It has to have value at every level for all parties," says Benneyan. Once medical staffers "get it," they will spread the word among other healthcare providers. One chief of surgery ended up blessing the use of computer simulation models to improve operating room workflows after discovering the similarities with academic medicine: Engineering students and research faculty were conducting clinical rounds, teaching while doing. "When we explain what we're doing, lightbulbs go off: 'That's what *we* do!'" Benneyan relates. Physicians discover that industrial and systems engineering helps them do their job better.

At Northeastern, healthcare systems engineering "offers a unique opportunity to expand upon the university's strength in, and commitment to, interdisciplinary, use-inspired research and education," says engineering dean Nadine Aubry, noting that health is a core research initiative. The HSyE approach also expands on the university's signature co-op model, she adds, with students bringing real-life knowledge and experience back to their peers and classes on campus.

The lessons typically begin with a crash course in hospital culture. At Northeastern's HSyE institute, clinician in residence Susan Haas primes students to ask deeper questions by describing the priority clinicians place on safety as well as the daily stress of dealing with life-and-death situations. Summer program lecturer Louis Freund, a professor of industrial and systems engineering (ISE) and director of the master's degree program in human factors and ergonomics at San Jose State University, spends the first two weeks in his capstone course going over medical jargon, data privacy rules, and other specific hospital-system concepts with students who are working on healthcare projects. "It was almost like an FAQ so we could at least prepare them a bit," explains Freund, who distilled the main points about how to start an ISE senior design project into an hour-long presentation – including examples from his students' trauma unit analysis – for Northeastern's summer institute. One piece of advice: Make appointments to see busy senior physicians, don't just drop by.

The induction "helped to get a standard [language] so we knew what we were talking about," says Virginia Tech industrial engineering senior Kelly Olliges, who joined Northeastern's summer program twice. "When you walk in as a group of 21- and 22-year-old undergraduates and talk to a medical doctor in a hospital, I felt a little intimidated. Some clinicians were excited to have us there. Others were: 'What can you possibly do for me?'"

The engineering students' lack of healthcare expertise can be an asset: It allows them to step back and spot systemic issues that might never occur to hospital staff. "A lot of times, they're so close to the problem themselves, maybe they're overlooking it," explains Cunningham. Just asking the right question can reveal shortcomings or unnecessary procedures. Working on blood-bank inventory optimization, he wondered why two units of plasma were thawed for every blood type each day, even though B was needed far less often than AB, the universal donor. "I don't really know," a nurse replied.

Building relationships and support for a project is crucial, underscores Freund, who recommends regular meetings with frontline staff as well as mentors. He also presents students with common signs of difficulties in the mentoring relationship that might affect the project's success. "Clinician buy-in was huge!" recalls Olliges, who talked to as many as possible and used data to persuade them. "They're scientists. If we can show better results, they will believe it." She and her team tackled such projects as discovering the source of delays in the early-discharge process (the majority of patients get discharged at 4 p.m. but must vacate their beds by noon) and documenting inefficiencies (time stamps on lab reports indicated long waits for results). "We followed the nurse manager around like little puppy dogs," she recalls. "During her break, we bought her coffee and asked, 'Can we talk to you for 10 minutes about what you did today?'" Armed with a process-format diagram, Olliges mapped out everyone's roles and highlighted chokepoints. Then, each week for the next eight weeks, she reordered the sequence of who did what and when, reducing overall wait times. Still, her methods brought occasional resistance: "One clinician felt we were looking at him under a microscope and telling him to go faster."

For engineering students, the career option of using industrial tools to benefit real patients and practitioners holds strong appeal – particularly among women, who tend to enter biomedical engineering for the same reason. "I want to feel my job's fulfilling," says Sarah Fisher, an Ohio State University industrial engineering senior, of her 2014 HSyE summer experience. She has gone on to take a lean six sigma certification course to learn methods for optimizing healthcare systems, and hopes to use her industrial engineering skills "to help people in the broadest and most impactful sense."

Virginia Tech's Olliges is stimulated by the varied challenges presented by 21st-century medical practice. "In manufacturing, the biggest outside resource constraint is whether a shipment is late or lost," she reflects. "There's not a constraint in insurance policy or safety standard." Her most rewarding project involved pinpointing an online-records software flaw that prevented teams of surgeons, radiologists, and nurses from developing collaborative care packages for cancer survivors, as Massachusetts state law requires. Before Olliges came, just three patients had received such comprehensive follow-ups. On her watch, 20 did.

Adoption of the ISE learning model in healthcare organizations can impose unique challenges unlike those a university would face working with industry. Just getting students credentialed and on site, for example, can consume the first few weeks of Freund's three-month capstone course, so semester-long projects rarely get beyond the recommendation stage. "There's a whole overhead to these projects" that must be considered when teaching healthcare systems engineering, he says. Freund notes that many hospitals require student project-related agreements with universities, such as the one San Jose State has with Santa Clara Valley Medical Center.

Since few of his healthcare system capstone teams will get to see their recommendations implemented by semester's end, Freund tries to keep students focused on the barriers or opportunities they've uncovered as well as the costs and benefits of potential solutions and recommendations. "I try to make sure they have opportunities to use the methods and skills we've taught them to perform their role as systems engineers intent on improvement and innovation," he explains. Freund, who meets weekly with students, reviews each one's contribution to the team and has the students sign off on sections of the group's final report. As in the real world, "their responsible for reading the whole report and collaborating on or correcting it if they feel that person didn't handle their section well." Students receive individual and team grades on their project reports. One memorable final presentation won the highest marks possible – from the medical center's entire staff, who turned to each other and immediately began asking why the problem was happening. "It meant to me they not only valued what the students were doing, it increased their understanding of their own operations," reflects Freund.

Graduates of HSyE's summer program are returning to their universities with ideas for using their experience. Already, Benneyan has graduates filling the breach on projects near their home campuses in Atlanta. By the end of this year, he calculates, more than 30 students and staff who have gone through HSyE will have been hired into another healthcare improvement role.

Virginia Tech senior Olliges intends to join them. Having discovered the power of industrial engineering to help people and heal broken healthcare systems during two summer institutes, she has embarked on a capstone project focused on improving the outpatient surgery process in a local clinic with low patient and employee satisfaction. She also plans to zero in on several healthcare consulting firms at the school's career fair this fall. Her 10-year goal is to work in a hospital as a logistics coordinator or operations chief.

While Olliges looks forward to "infecting healthcare with industrial engineers," her mentor Benneyan is pondering new frontiers, including how to get funding for training and education rather than project-specific grants and an ambitious undertaking to use process modeling and statistical analysis to create a way to screen infants for autism. He also hopes to investigate the potential for "cohort co-ops" to dramatically increase learning and innovation. His biggest lesson so far: "Get good people, put them in an environment where it's fun to work hard and learn hard, and they'll create some amazing things."

Mary Lord is deputy editor of Prism.

NORTHEASTERN'S JAMES BENNEYAN, SHOWN AT RIGHT WITH HEALTHCARE SYSTEMS ENGINEERING SUMMER INTERNS, CONTENDS THAT 70 PERCENT OF HEALTHCARE PROBLEMS CAN BE REMEDIED BY REORGANIZING SUPPLY CABINETS AND OTHER FRONTLINE FIXES.

Virginia Tech senior Kelly Olliges, who participated twice in Northeastern's summer program:

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