



Global Educators Network for Health Innovation Education

**EDUCATING LEADERS WHO CAN ACCELERATE HEALTH
CARE INNOVATION:
WHAT YOU SHOULD DO TO MAKE IT HAPPEN**

Overview. *Innovation is accelerating across the health care world. Every sector pursues breakthroughs in quality; cost; access; speed; and new technologies to close the gap between demand and supply for health care.*

Tomorrow's health care leaders will require new skills, behaviours, and processes—competencies that are not adequately taught today. The time has come for all of us in health care to embrace the need to transform traditional management teaching models.

The new model will produce leaders who have studied real world examples of innovation leadership. They will have practical experience building business models and creating action plans for new models of care. They will develop skills in collaboration, team building, and customer engagement that will drive industry innovation. They will be especially attuned to the power of great talent, and will understand how to attract and empower the best people to achieve breakthroughs.

“I’d rather not make a clinic more efficient. I’d rather start a new one that has a radical set of assumptions. You have to start thinking from scratch.”

--Vinod Khosla, Venture Capitalist and co-founder, Sun Microsystems¹

The **Global Educators Network for Health Innovation Education (GENiE)** was organized to meet these needs by spearheading health care management education innovation. GENiE’s specific mission is to transform the education and preparation of future health care leaders by garnering support and resources to ensure that virtually all health care management degree students and executives are educated with the skills, knowledge, and mindset to spur crucial innovations in health care. Its objective is to fulfill this mission in ten years and then disband.

THE HEALTH CARE INNOVATION OPPORTUNITY

By now it is a truism that the health care system is overwhelmed by exponentially rising costs, ineffective patient care, and unequal access. The 21st century has witnessed astonishing advances in medical research, such as mapping the human genome and personalizing cancer drug therapies, yet the number of avoidable hospital deaths per year are up to 400,00 in the U.S. alone.² Add to that steadily increasing costs and the demographics of an increasingly aging population and we have an on-going global crisis rife with unprecedented demands for innovative reform.

Health care leaders are well aware of the urgent need for innovation. When Professor Regina Herzlinger and her team at the Harvard Business School interviewed 59 of the world's most innovative CEOs in health care about their future needs, along with associated Human Resources (HR) personnel, the words the interviewees used most often were "change" and "innovation." The CEOs and HR administrators expressed a clear need for executives who can investigate problems, find solutions through process and organizational innovation, and drive them forward—people who can work on a diverse team, understand failure and its causes, and manage change.³ Comparable surveys of the top health care executive search firms conducted by Professor Herzlinger and Professor Eugene Schneller of Arizona State University, however, revealed that strong leaders who can meet the challenge to motivate and implement innovation are in short supply.⁴ **(See Table 1: Health Care Innovation Leaders: Demand and Supply.)**

Table 1: Health Care Innovation Leaders: Demand and Supply

	Health Care CEOs(1)	Human Resource Leaders(1)	Key Health Care Recruiters(2)
Demand			
Skills in business innovation	X		
Focus on processes and business models, incentives, more than products	X		
Understand big picture trends	X	X	
Skills in Communication, team building			X
Consumer-centric skills			X
Supply			
Academia does not produce for our specific needs. We provide significant training.		X	
Still teaching people who want to be hospital administrators			X
Understanding business drivers is critical and often a bigger challenge (for) our scientists – clinicians, and public policy experts		X	X

(1) Scriplogix, Factors that Influence the Shaping of Talent in Health Care, and Survey of CEOs, Heads of Firms, HR, and Participants from Academia, August 2012.

(2) Regina E. Herzlinger. Presentation from GENiE Conference, University of Alabama at Birmingham, May 2015. *Global Educators Network for Health Care Innovation. A Health Care Innovation Education Agenda: Building Curriculum and Community.*

What is the root cause of the gap between, on the one hand, the demand for leadership that can spur innovation, and on the other hand, the scarce supply? The answer can be summed up in one word:

Education

Academics today are aware that schools are not educating students to innovate the processes, systems, and organizational forms that could solve health care problems. **(See Table 2: Impediments to Teaching Health Care Innovation.)** Despite the health care sector's massive share of the GDP—17% in the U.S., and elsewhere, mostly more than 10%—most graduate health care administration and medical programs have not aligned their curricula to address the pressing need for innovation. Recent analysis of health care related curricula at 26 top U.S. schools that offer graduate degrees in health care administration found the most frequently used words were not the much-needed “change” and “innovation” but passive words such as “public policy” and “organization.”⁵

Table 2: Impediments to Teaching Health Care Innovation(1)

- 1. Faculty Skills and Mindset**
 - a. Shortage of faculty with relevant health care knowledge in schools of Business Administration
 - b. Shortage of faculty with relevant managerial skill sets in schools of public health/health administration
 - c. Excessive number of tenured faculty who are unwilling to change their curriculum
 - d. Shortage of faculty who use the case method of instruction
 - e. Shortage of faculty who are knowledgeable about the following areas of interest: health IT, health care delivery, entrepreneurship/venture capital
 - f. Absence of holistic perspectives and knowledge of global markets and how they impact health care in any economy
- 2. Logistics**
 - g. Cross-registration – we do not currently require physicians or aspiring health professionals in schools of medicine or public health to take business courses
 - h. Uncoordinated class schedules
- 3. Curriculum**
 - i. Balance of standardized curriculum vs. innovation/leading-edge curriculum
 - j. Utilization of evolving contemporary technology delivery tools that provides meaningful long term adult comprehension of content
 - k. Limited framework to determine value (value based payment based on indicators, not market assessment of value).
 - l. Difficulty translating “health” way of thinking into “management” and vice-versa
 - m. More ideology than evidence behind policy issues
 - n. Scarce access to strategic data from real life organizations

1) Scriplogix, Factors that Influence the Shaping of Talent in Health Care, and Survey of CEOs, Head of HR Firms and Participants from Academia, August 2012.

The bottom line is that for health care to change, the education of our health professionals and health administration leaders must change. Academics, CEOs, and recruiters agree that innovation can be taught. We know what health care education must look like to meet the challenges and pursue opportunities for innovation. (See **Table 3: Key Health Care Innovation Education Competencies**).

Table 3: Key Health Care Innovation Education Competencies			
	Health Care CEOs(1)	Human Resource Leaders(1)	Key Health Care recruiters(2)
<u>Curriculum</u> <ul style="list-style-type: none"> • Reduce silos in finance, medicine, etc., and focus on holistic, real life curriculum • Structured long-term mentorship • Less analytics, metrics, outcome education • More behavioral and incentives education 	<p>X</p> <p>X</p> <p>X</p>		X
<u>Lifelong learning</u>			X
<u>Active Learning</u> <ul style="list-style-type: none"> • Courses that require teamwork in innovation • Case studies 			<p>X</p> <p>X</p>
<u>Recruit Different Students</u> <ul style="list-style-type: none"> • People who want to do entrepreneurial things. • People who can lead change • Proven health care backgrounds • People who can “tell a story” • People who can see the future • People who can tolerate failure and take risks 	<p>X</p> <p>X</p>		<p>X</p> <p>X</p> <p>X</p>
<p>1) Scriplogix, Factors that Influence the Shaping of Talent in Health Care, and Survey of CEOs, Head of HR Firms and Participants from Academia, August 2012.</p> <p>(2) Regina E. Herzlinger. Presentation from GENiE Conference, University of Alabama at Birmingham, May 2015. <i>Global Educators Network for Health Care Innovation. A Health Care Innovation Education Agenda: Building Curriculum and Community.</i></p>			

A HUMAN RESOURCE LEADER SUMMED IT UP:

Human Resources:

So if I were in your shoes, here is what I would do:

- Focus on selecting students with the right talent to lead change in your organizations.
- Select students with the skills that are hard to develop (ambiguity tolerance, adaptability, and cultivating innovation) and focus development efforts around skills that are easier to learn (managing complexity, cultural dexterity, and self-awareness).
- Teach them how to create innovative teams and set the conditions by which people can catch up with the changes happening all around them.

Human Resources:

What North American health care executives don't share with highly successful, innovative leaders is the ability to effectively drive change through their organizations.

It's not enough to be a one-man or a one-woman innovator. Driving change involves inspiring others, gaining buy-in from diverse stakeholder groups, making operational and strategic changes that help their organizations transform over time. This includes developing talent, tracking performance, developing innovative leaders. It also involves being self-aware as a leader, knowing how to build high performing teams, and leveraging employees with wide-ranging, diverse skill sets.

Regina Herzlinger. GENiE Conference, 2015, University of Alabama at Birmingham presentation. *Global Educators Network for Health Care Innovation. A Health Care Innovation Education Agenda: Building Curriculum and Community.* May 5, 2015. <https://www.dropbox.com/s/z6g8nkkmalml1uia/Conference%202015%205%205%2015.pptx?dl=0>

GLOBAL EDUCATORS NETWORK FOR HEALTH INNOVATION EDUCATION

We take heart from the recent emergence in business schools of entrepreneurship as its own field of teaching and scholarship. A generation ago, one rarely heard the term "entrepreneur" in business schools. Today, entrepreneurship programs stand alongside accounting, finance, and management as core pillars of business curricula. Currently 360 colleges or universities in the U.S. offer degrees in Entrepreneurship.⁶ We believe a similar curricular change is imminent in health care education.

GENiE was created to make innovation a central part of the education of future leaders in health care. It represents diverse, global academic institutions and health care organizations dedicated to teaching innovation to future leaders. More than 400 stakeholders are academics who are actively introducing innovation into their

curricula or CEO champions who share these interests, including the CEOs of Johnson & Johnson, the American Medical Association, and aethenahealth, Inc., among others.

To further these partnerships, GENiE has held four major conferences of stakeholders at Harvard Business School (2012), Duke University (2013), University of Alabama at Birmingham (2014), and the first European edition, hosted in October 2016 by IESE Business School in Barcelona.

GENiE is creating an archive of innovative programs; producing a series of videos, which highlight the importance of health care innovation, businesses that support it, and students who become health care entrepreneurs (<http://www.thegeniegroupp.org/innovation-health-care-collaborations-and-programs/>); and collecting surveys of a wide range of constituents to help identify the competencies necessary in an innovation curriculum.

These conferences feature the curriculum of, among others, the HBS MBA courses on Innovating in Health Care, the Harvard edX MOOC Innovating in Health Care (<https://www.edx.org/course/innovating-health-care-harvardx-bus5-1>) and the HBS Executive Education course Business Innovations in Global Health Care (<http://www.exed.hbs.edu/programs/big/Pages/default.aspx>).

The videos below contain some of the many success stories this kind of education has enabled:

- *Student Health Care Entrepreneurs*
https://www.dropbox.com/s/4ztjvmq2a75rayk/segment_02_revised_2016_PP_T_large.mov?dl=0
- *Go Health*
<https://www.dropbox.com/sh/zbuti05imsjivyp/AAAn1fqMynS1F3hVy9-N3Jbta?dl=0>

HEALTH CARE INNOVATION FUNDING

Current public and private funding for health care reflects the growing demand for innovation that will ameliorate the underlying problems in health care systems and the recognition that this is a time of enormous opportunity for entrepreneurial change.

Private funding--corporate venture capital, private equity and incubator/accelerator funding --- of health care delivery, IT, insurance, and medical technology is active and rising. Significant allocations for stepping up innovation are also found in the public sector. In the U.S., the Center for Medicare and Medicaid Services (CMS), and in the U.K., the National Health Service (NHS), have both created innovation centers to support, develop, implement, and promote innovation initiatives that promise to

improve patient care, lower costs, and improve the health of the population. In Europe, the European Institute of Innovation and Technology (EIT) has formed EIT Health, a consortium that promotes research, education, and business expertise to “accelerate entrepreneurship and innovation in healthy living and active ageing with the aim to improve quality of life and healthcare across Europe.”⁷

Venture Capital Health Innovation Funding

Health Insurance. Health-insurer and insurance-technology startups raised more than \$1.2 billion in venture funding in 2015. That's more than double the \$570 million raised in 2014, and 10 times the \$123 million raised in 2013.⁸ Innovation in the health care insurance industry seeks to contain costs and improve the experience for providers and patients.

- Oscar, for example, which sells insurance directly to consumers, offers members free, unlimited access to telemedicine and some preventive care.⁹ By using existing health technology innovations, the five year-old start up offers members video chats with doctors and a website that helps them track and manage visits and personal health information.¹⁰
- Clover Health also integrates technology into patient care, but differs from Oscar in providing coverage for Medicare Advantage patients only.¹¹ Clover's innovation is to reduce hospitalizations and other high medical costs by proactively using lab results, prescription orders, and electronic medical records to identify those consumers in need of regular care for chronic illness and then intervene to reduce hospitalizations and other high medical costs.¹²

Digital Health. Nearly \$200 million was invested in population health management start-ups in 2016, making it one of the top six fields in health care attracting new money. The other five top fields are analytics and big data, wearables and biosensing, telemedicine, and digital medical devices.

- For example, Rahul Jain and Nick Valilis, both named as Forbes' “30 under 30” list, co-founded TowerView, a low-tech prescription management service that arranges with a patient's pharmacy to receive a medication tray of their daily medications. When a patient misses their medications, a cellular device sends a text, phone, and in-box reminder to patients, loved ones and case managers. TowerView also handles the prescription refills.¹³
- AMINO¹⁴ and Health Engine¹⁵ are *direct-to-consumer information providers* that open the line of sight to out of network options for care and technology that can provide quicker access to care, at lower cost. They can help make appointments as well. HealthEngine also has relationships with insurers to encourage splitting the savings in cost with the consumer. Both manage huge amounts of information that will allow better measures of cost and quality, which will further accelerate competition in health care.

Personalized patient care delivery makes innovative use of technologies to provide health care directly to the patient. Aspire Health offers personalized outpatient palliative care; Docent Health partners with health care organizations to deliver holistic cancer care; Circulation partners with car driving services to provide transportation to Doctors' appointments for seniors and home delivery of flu shots. Partnering with physicians, Quartet uses digital technology to provide behavioral health assessments, identify individuals in need of behavioral health resources, and match those individuals to providers or self-care treatment paths.

Corporate Health Innovation Funding

Corporations are also heavily involved in fostering health care innovation. For example,

- *Aetna Innovation Lab* brings together physicians and technology experts within Aetna to develop innovations to improve healthcare for patients and providers. Innovation projects that have come to fruition include a personalized wellness program to help people with metabolic syndrome; a mobile app to connect breast cancer patients with one another, and a Tai Chi program to reduce falls for seniors.
- *Johnson and Johnson Innovation*, which “help[s] entrepreneurs realize their dreams of creating healthcare solutions that improve peoples’ lives around the world,”¹⁶ has developed a global network of incubators that spur collaboration and support innovations in consumer health, medical devices, pharmaceuticals, and global public health. *JLABS* sponsors competitions for game-changing, early-stage innovation—winning entries are awarded funding, lab space, a support team and access to a global network of industry experts. *Innovation Centers*—located in Boston, California, London and Shanghai—serve as hubs in high-growth science and technology regions to support and collaborate with entrepreneurs wishing to develop early-stage consumer or medical devices and biopharmaceutical companies seeking to advance a program which is pre-proof of concept in humans. *JJDC, Inc* offers strategic venture partnerships and invests across all health care sectors and at all stages, from seed-level start-ups to Series B and beyond.

Public Sector Health Innovation Funding

The public sector also handsomely supports health care innovation. For example,

- *The Center for Medicare and Medicaid Innovation (CMMI)* was created by the Affordable Care Act and funded with \$10 billion for 2011-2019 to test new payment and service delivery models. These included Accountable Care Organizations and Primary Care Transformation as well as partnering with local and regional stakeholders to spread local bottom-up innovations. For

example, The Comprehensive Care for Joint Replacement (CJR) model tests bundled payment and quality measurement for an episode of care associated with hip and knee replacements to encourage hospitals, physicians, and post-acute care providers to work together to improve the quality and coordination of care. An episode of care begins with a Medicare patient's hospital admission in a participating hospital and ends 90 days post-discharge. Financial incentives and disincentives are based on the actual price of care in comparison to the Medicare target episode price.¹⁷

- *Great Britain's National Health Service (NHS) launched its Innovation¹⁸ Accelerator (NIA) in 2015, to nurture innovators and entrepreneurs within their system. The NIA began with 17 innovations, ranging from digital devices to diagnostics. In its first 6 months, it claims to have benefitted 3 million people and that, after its first year, innovations were placed in more than 380 NHS organizations. For example, MyCOPD, a patient IT self-management system for pulmonary rehabilitation (<https://mymhealth.com/>) was designed by a physician-innovator who was awarded a public grant, enabling him to reduce his clinical time to focus on the innovation. The NIA matched the innovator to a high-level innovation mentor, provided advisory support with writing contracts and bids to appropriate funders, and evaluated the innovation's cost-efficiency. Finally, the NIA navigated the vast NHS system to match MyCOPD to locations where it could have the most impact; e.g. hospitals with high disease incidences. In another example, the NIA worked with an American company, AliveCor, which had developed an EKG device that attaches to a smartphone (<https://www.alivecor.com/en/>). The NIA set up pilots and partnerships in North-East London that would redesign physician services to effectively deploy the new device, one which enabled general practitioners to monitor a patient in 30 seconds in their offices instead of scheduling time-consuming and costly visits to an EKG machine. Once the service redesign cost and time savings had been demonstrated, the NHS negotiated a bulk purchasing price, to purchase larger orders of the device for wider use in the system, allowing front-line clinicians to request and prescribe the device, with the assurance it would be reimbursed.*
- *The European Union launched EIT Health with a budget of two billion Euros for the next ten years. With headquarters in Munich and six co-locations across Europe, EIT Health brings together over 145 leading health care companies across multiple industry sectors, public and private research centers, and top universities. Their goals are ambitious: between 2016-2018, they expect to create 165 start-ups and launch another 160 new services and products; enroll one million students per year in online educational programs; and incubate approximately 340 new business ideas.*

The EIT Health network educates through three “pillars” – Campus, Innovation Projects, and Accelerator.

Campuses are week-long summer programs, held across Europe, open to students/PhDs in science, engineering, and business; industry entrepreneurs; executives; and citizen-scientists. Participants learn basic business skills through case-study discussion and lecture-presentation and work intensely in interdisciplinary teams to translate innovation ideas into business plans they pitch at the end of the session.

Innovation Projects. EIT Health posts an annual “call” for innovation project proposals that originate either in a design idea or an identified proven need in health care. Collaborative, multi-disciplinary teams apply with at least one academic and one non-academic partner and are funded for one year. Proposals are rigorously evaluated by an external review panel of experts according to criteria that includes the excellence of the proposal and team knowledge; commercialization potential and market strategy; impact.

A sampling of the wide-ranging 23 innovation projects for 2016 include: patient self-care apps for diabetes, dementia, healthy lifestyles; implementing standardized adult osteoarthritis care for general practitioners; technology to speed up acute stroke treatment; using existing medical imaging technology to improve dementia diagnosis and assessment; and a common data sharing platform for six cancer centers and pharmaceutical developers to identify patient responses, leading to a multi-site European cancer institute.

Accelerator strives for a “river of validation” from the beginning to the end of the innovation process. The four major steps are Incubate, when student teams undergo four weeks training followed by a four-week tour through Europe to pitch to partners; Validate, when teams are given access to mentors, pilots, testbeds, and reimbursement experts from a database of partners; Scale up, when startups pitch to investor network/crowd-funding platforms and compete for a prize of 50K euros; and Scale out, when the innovation connects to larger ecosystems and goes global.

Public-Private Partnerships

Sometimes health care innovation is supported by public-private partnerships.

- The Tanzanian government has committed \$1.8 MM to build a new cancer treatment facility on the same property as a large academic medical center. There is no chemotherapy or radiation therapy in the region, yet there is a high rate of cancer. The technology for The Cancer Center in Tanzania will be provided by a Minnesota based,

physician-run nonprofit that will raise donations and persuade the major technology providers to emphasize the "do good" part of their business model to install and operate the center. The on-ground talent to operate the center will be provided in part from two Minnesota-trained physicians who have been practicing in Tanzania for decades.¹⁹

EDUCATING FOR HEALTH CARE INNOVATION

It is not enough, however, to simply fund a slew of innovations and throw them against the wall to see which ones stick. Far too many innovations fail, often because the innovators are unprepared for the complexities of the health care environment. In other cases, innovators have designed ineffective business models. Education can help prepare innovators to design viable, do good/do well business models that align with the conflicting interests of the many stakeholders in the health care landscape.

The Appendix contains example of programs in health care innovation offered in schools of administration, medicine and nursing, and interdisciplinary settings. It also illustrates innovation programs in information technology, medtech and bioengineering.

CALL TO ACTION

Academia suffers from a shortage of business educators who are knowledgeable about health care delivery and insurance, health IT, and medical technology.²⁰ Public health and health administration faculty, on the other hand, often lack knowledge of appropriate managerial skills, entrepreneurial approaches to global health, venture capital, and the case method. Too often, these programs are based on public policy, and based on traditional hospital and payor models rather than practical, scalable innovation solutions.

These shortcomings go hand-in-hand with faculty resistance to curricular changes entrenched academic incentives to publish and conduct traditional research rather than to foster innovation projects and innovate curricula. Additionally, scholars may have difficulty accessing data on real-world organizations or course material that integrates health care and business school curricula.

Academics

"Health care innovation needs the type of people who run and build companies: driven, charismatic, narcissistic personalities who have a clear strategic vision and who get the job done. People who are blinded by their own desires."

--Regina Herzlinger, founder, The GENiE Group

What can you do to help? The call to action requires:

- A concerted effort for academia and industry to join forces to move the agenda forward, which can take the form of collaborative, periodic meetings, or other means of fostering exchange on issues and progress in promoting innovation;
- A showcase for effective innovations that have improved quality and/or improved efficiency, and how;
- The development of tools to foster learning and appreciation of innovation;
- The dissemination of good practices through (a) case studies, (b) papers, (c) a learning collaborative and clearing house on innovation practices, and on teaching how to promote innovation in an academic environment.

Innovation education should begin with recruiting the kinds of students with the personalities best suited for innovation: people with diverse experiences and backgrounds who demonstrate entrepreneurial skills; original minds; willingness to take risks; and an ability to grow an organization. Our survey data demonstrate this.

Academics should instill an innovation mindset in these students with focused, activity-based, holistic course material. This includes:

- Reading and discussing case studies and inviting local entrepreneurs to advise students and engage in dialogue.
- Student teams that craft rigorous and effective business plans that are judged and awarded funding by local entrepreneurs, venture capitalists, and angel investors.
- Enlisting local mentors and entrepreneurs who will offer internships and career opportunities.

Health care innovation education can benefit from interdisciplinary teams composed of professionals in business, finance, engineering, public health, and medicine who have been trained to work together, understand how the other players in the health care ecosystem think, and are knowledgeable about local and national political processes. To change health care education to meet these goals, academics and industry leaders must each put in an oar in order to guide this ship of many sails toward a sea of opportunities and breakthroughs.

Industry Leaders

Industry should support the call to action by providing personal resources and financial support that will efficiently and effectively enable academics to educate future innovation leaders. The activities below can help to fuel the pipeline.

- Collaborating with academia on the latest innovation developments and the curricula they require.
- Initiating the training programs that focus on leading innovation.

These challenges define the "Educate > Hire > Innovate" paradigm of innovation: educators teaching the concepts of health care innovation, employers hiring graduates with these skills, and innovation accelerating from this collaboration, leading to new pedagogies. The process of educating, hiring, and innovating, by more closely linking and facilitating the exchange of information and needs at each stage between employee and academics, accelerates innovation in a continuing virtuous cycle that benefits all participants.

LAST WORDS BEFORE WE GO

Demand for health care innovation is at an all-time high, and all signs point to its continued acceleration. Significant progress has been made in health care innovation education in the past few years; the descriptions in this white paper represent only a sample of the growing number of programs, courses, and collaborations, many of which benefited from GENiE's support. Worldwide, the recognition that health care education must include innovation is taking hold.

But there is still a long way to go. Time is of the essence, especially in a world where political and regulatory landscapes shift dramatically, technology is developing at an astonishing pace, costs are rising exponentially, and an aging population is greatly expanding. For GENiE to fulfill its mission of transforming the education and preparation of future leaders in health care innovation, we need a sustainable pool of resources—financial, social, and educational.

Please help us make this happen.

The GENiE Team

APPENDIX: EXAMPLES OF HEALTH CARE INNOVATION PROGRAMS IN DIFFERENT ACADEMIC SETTINGS WITH DIFFERENT FOCI

Health Care Innovation Education in Schools of Administration

Schools of administration, whether of business or health care, are well positioned to take a leadership role in health care innovation. Building on their expertise and incorporating the perspectives of different stakeholders to frame current health care problems, these institutions can foster the development of innovations and provide examples of how to implement them. Some of these programs blend residential and online learning so students, who often create an innovation project that directly impacts their organization, can continue working while enrolled.

- Innovation is a principal theoretical frame for courses at *Arizona State University W.P. Carey MBA Health Care Management*, especially in health care organization and the health care supply chain. Students are required to assess an evolving innovation on the basis of its applicability to the health care value chain and potential to meet triple aim goals; e.g. innovative technologies designed to reduce pressure ulcers and wearable biosensors. The courses have a “global focus” and require students to assess innovative approaches in the health sector in both developed and emerging economies. In the courses, students are introduced to a change management approach designed to challenge them to consider innovation diffusion, adoption, and management. Courses bring together students from the MBA day, executive, and evening platforms, and rely on instructor-led discussions, case material review, and guest lecturers from organizations with innovative products and processes.
- *Brown University, (Professional Studies) Executive Master of Healthcare Leadership*, is a sixteen-month program designed for clinicians, executives, administrators, and other stakeholders across the health care system who want to transform health care. It blends residential and online learning, so students can continue to work full-time. Innovation is emphasized across the curriculum. All participants are required to work on an independent innovation project that stems from a critical health care challenge they have identified, often in their own organization, with collaborative, cross-sector input from peers, professionals, and professors.
- *Duke Institute for Health Innovation (DIHI)* Housed within Duke University and the Duke University Health System, DIHI connects broad expertise and resources across Duke to address important health care challenges and pilot innovative health care projects. DIHI has four areas of innovation, including Health Technology Innovation, Implementation and Health Delivery Science; Health Leadership Development; and Applied Health Policy. DIHI runs a Living Lab for innovation within existing clinics in the university health system to test new delivery models that promise to improve patient care, increase access, and lower cost. Innovations include access to data, analytics and visualization, project management, measurement and evaluation (both clinical and economic), and the ability to disseminate the innovation. Connections to industry are ongoing.
- *The Haas School of Business Graduate Program in Health Management (GPHM)* prepares Berkeley MBA students to become leaders who can deliver both innovative and practical solutions in health care. It trains students to understand the broader health care environment while developing specialized knowledge and skills for leadership innovation positions in all aspects of healthcare, including care delivery and financing, biotechnology and medical devices, information technology, and consulting. Courses offered as part of the MBA, and through a dual MBA/MPH degree program include:

Healthcare in the 21st Century; Changing Healthcare Economy; Innovations in Healthcare; Biotech/Pharma; and Healthcare Finance.

In addition, GPHM offers applied learning experiential courses focused on non-profits (Social Sector Solutions) and international organizations (International Business Development). The student-run Haas Healthcare Association offers a health care speaker series, an annual *Business of Healthcare Conference*, San Francisco Bay Area company treks, and Hack2Health, a digital health hackathon which most recently focused on innovations in diabetes care.

- Harvard Business School (HBS) launched its *Health Care Initiative (HCI)* in 2005, and offers courses, industry speakers, career coaching, treks, and alumni engagement for aspiring health care innovation leaders. Elective courses for MBA and MBA/MD students include Entrepreneurship in Health Care IT and Services, Innovating in Health Care, Transforming Health Care Delivery, and support for student projects that innovate solutions to real-life health care challenges. For the Annual JP Morgan Healthcare Conference, the HCI hosts a networking reception in San Francisco for alumni working in all sectors of health care. In 2017 there were more than 300 in attendance, including alumni from Harvard Medical School (HMS), the Kennedy School of Government, and the School of Public Health, as well as recruiting partners and prospective students. In addition, HBS and HMS partner in The Forum on Health Care Innovation and sponsor a Health Acceleration Challenge that focuses on proven, already-implemented health care solutions and helps them to grow and increase their impact through powerful networking and funding opportunities. Winning innovations receive cash prizes and become subjects for HBS case studies.
- *St. Petersburg University, Russia, Graduate School of Management Health Management Program.* Consisting of more than 20 courses, the program enrolls about 30 company executives in an eight-month program that combines full-time modules, distance education, and a final assessment. Students are incentivized to extract from each course the information necessary to develop their individual or team projects. Teams are designed for diversity and organized around members' geographic region; whether they work in the public or private sector; the type of organization; and their organizational position and educational background. Capstone projects develop the innovative strategy of students' home organizations; e.g., complex managerial changes; the creation of new markets; or significant and quick improvement of a company's long-term market position.
- *University of Alabama Collat School of Business* offers MBA students (and non-MBA graduate students in science) a Graduate Certificate in Technology Commercialization and Entrepreneurship. The program is designed to blend knowledge and experiential learning to help move scientific discovery and

- inventions out of the lab and into the marketplace. The three course sequence—Planning and Pitching a New Business Concept; From Idea to IPO; and Leading Innovation—takes the student from general awareness of issues associated with technology commercialization to running a growing technology-based business. Industry guest speakers and student innovation projects are emphasized throughout.
- *University of Minnesota Carlson School of Management Medical Industry Leadership Institute (MILI)*, established in 2005, offers students innovative training, knowledge, and experience through industry-specific courses and hands-on evaluations of emerging technologies. MILI both draws on the expertise of University of Minnesota researchers working in scientific, technical, legal, and ethical areas and offers national and international firms access to their intellectual community of faculty and students.
 - *The Medical Industry Valuation Laboratory*, offered three times each year, brings together an interdisciplinary collaboration of students, faculty, and industry leaders. This collaboration educates students in understanding the primary issues facing medical industry giants such as Boston Scientific, Medtronic, 3M, and St. Jude's, as well as new medical device start-up companies. Graduate students from the Institute of Technology, the Carlson School of Management, the School of Law, College of Liberal Arts, and the Academic Health Center form interdisciplinary teams to evaluate new medical innovations from private clients and University of Minnesota researchers. Supervised by faculty and mentors, students produce a comprehensive valuation report covering all aspects of the medical innovation, including intellectual property issues, regulatory challenges, market size and growth trends, the effectiveness of and need for the technology, financial issues and strategic positioning.
 - *University of Toronto Rotman School of Management Health Sector Management* program trains future innovation leaders to create a balance of access, cost effectiveness, and quality services in the health care and life sciences sector in Canada and globally. In part reflecting the tensions between public and private actors in the Canadian health care system, the program emphasizes managing interactions among health care payers, providers, scientists, and commercial suppliers.

In addition to general management skills, the curriculum includes courses in life sciences innovation. A year-long “Link and Learn” seminar series addresses key elements of the health system (e.g., information technology, procurement, global health, entrepreneurial activity, med-tech strategy), with an interdisciplinary group of MBA students, scientists, other university units, and members of the commercial health and life science community.

Ongoing career nights enable students to engage with local executives; domestic and international case competitions; and faculty-student-alumni dinners.

Rotman's programs include an MBA degree with a specialization in the health and life sciences (a two-year program) and a forthcoming Global Health and Life Sciences Executive MBA program. Non-degree professional programs include an Advanced Health Leadership program for executives as well as customized programs.

Health Information Technology Innovation Education

The health care industry is a late adopter of IT innovations (relative to other industries, such as finance, entertainment, and retail), but the use of information technology and mobile health applications within this sector has recently begun to explode. As data from health care providers and payors become ubiquitous, entrepreneurs are capitalizing on the opportunity to make sense of it. Innovative start-ups are utilizing 'big data' and mHealth to offer solutions that improve quality, lower costs, and streamline access to health care services.

- *At Harvard Business School, Robert Higgins' course, Entrepreneurship in Healthcare IT and Services*, examines a series of innovations within the burgeoning HCIT industry, and considers the decisions entrepreneurs face as they refine their business models, innovate, and grow. Among other learning objectives, the course analyzes business models, discusses how innovators make strategic decisions to find the "killer app," surveys funding avenues available to new ventures, and discusses the need of various stakeholders to lower costs, manage risks, and improve care.
- *At Saint Louis University's Department of Health Management & Policy, Mark Gaynor's course, IT and Operations* includes a three-unit module about health care innovation technology. Lecture and discussion about traditional and emerging innovation models begins with the simple linear model of innovation where a product or service moves from basic research to mass production and marketing. The discussion then moves to more modern models such as the Open model where innovations come and are integrated from many areas and the Six Factor innovation model developed by Regina Herzlinger at Harvard Business School. Technology adoption models include TAM, Innovation Diffusion, S-curves and cascading S-curves, and the Gartner Hype Cycle. The second module covers the topic of disruptive innovation. The module ends with student-teams presenting HBS case studies: *Hub and Spoke*, *Health Care Global*, and *Additional Focused Factory Models for Cancer Care*. These cases serve to integrate the many innovation models discussed.

Medical schools, cognizant of the increasing role that technology plays in health care, are offering programs in informatics that provide training in data standards

and modeling conventions, population health data, aggregate data modeling and data visualizations.

- *Duke University School of Medicine Masters of Management in Clinical Informatics* aims to teach students how to use information technology to drive innovation in health care. The twelve-month, full-time program meets on weekends to accommodate working professionals—study teams work together by teleconference during the week. Students must also complete a practicum in healthcare. The program includes industry speakers, regular networking opportunities, and career support tailored to students' individual goals and interests.
- *Harvard Medical School's Department of Biomedical offers a Master of Biomedical Informatics (MBI)* degree that trains students to be proficient in applying a broad range of data science approaches, methods, and techniques. The program includes an intensive, hands-on boot camp, a range of foundational courses in quantitative and biomedical subjects, as well as courses in emerging areas such as precision medicine and data visualization. Experts from the community mentor students. Students complete a capstone research project and participate in a longitudinal seminar series.

Interdisciplinary Health Care Innovation Programs

Partnerships among schools of business, engineering, health care administration, medicine, public health administration, public policy, and science can additionally educate students about innovation by offering interdisciplinary courses that involve case studies, industry experts, and real world experiences. These interdisciplinary partnerships, offered by schools of administration and medicine, are also beginning to appear in undergraduate schools.

- *Arizona State University Master in Healthcare Innovation (MHI)* is an interdisciplinary, fully online degree program that prepares students to design, implement, and lead transformation in health care by navigating seven pillars of innovation (policy, evidence-based practice, outcomes, leadership, finance, technology/communication, and the innovative process). Students develop innovation thinking throughout the course sequences and collaborate cross-sector with professionals and faculty. A graduate certificate in Health Care Innovation is also available for non-degree seeking students. Students in both programs develop a capstone project demonstrating proficiency in innovation science and application.
- *Imperial College Health Partners (IChP)* brings together National Health Service providers of health care services, physician-led management groups, and academic researchers across North West London. They aim to enable the discovery and adoption of emerging innovations in health care; support the adoption and diffusion of existing best practice and innovation at pace and

scale; and develop an innovation-friendly culture and marketplace, strengthening capacity to partner with academia and industry.

One ICHP project, online tool, “Navigating the Innovation Pathway,” developed by Imperial College Professor James Barlow, guides academics, clinicians, or small companies involved in researching and developing new medical devices or applications. The tool is organized around six stages of the innovation journey: preliminary research; basic technology research; feasibility and development; demonstration; testing & launch; adoption & spread. The website provides information and links to many potential sources of funding as well as exercises, checklists, and educational instruction for each innovation stage.

- *University of Barcelona* offers a nine-month master’s degree program, *d-health Barcelona*, in which four-person interdisciplinary teams composed of students with backgrounds in medicine, engineering, management, or design spend five weeks in an introductory “boot camp,” followed by a two months’ immersion experience at one of several leading Barcelona hospitals. At the hospital, the teams follow daily routines and medical protocols to identify unmet needs. They are required to innovate a solution to a real need they have identified and finally, to pitch to investors for funding. Students spend most of their time with mentors, called “industry executives.”

The program estimates its innovation outcomes as meeting 30% hospital/health care improvement needs; 8% scientific discovery needs; and 62% business needs. It aims to teach a process rather than a course of knowledge. It was created under the assumption that healthcare is moving from a bench-to-bedside trajectory to a needs-based innovation environment.

Innovation Programs in Medical and Nursing Schools

Medical schools have picked up the challenge. As Joel Daboub, the director of admissions at Dell Medical School at the University of Texas said, “We’re not just training people to be physicians . . . but to be leaders who can take responsibility and create solutions.”

The traditional medical education, built around two years of basic science learning in the classroom, followed by two years of clinical work, needs revision. Medical education in the 21st century must focus on real world, hands-on-experience, and include learning the physician’s role as part of a caregiving team and as a player in the wider world of health care that includes insurance companies, government regulators, and life science industries.

What might that education look like?

- *Arizona State University's College of Nursing and Health Innovation (CONHI)* incorporates innovation into the curriculum beginning with incoming freshmen and continuing through graduate degrees and certificates at the doctoral level. Freshmen enrolled in the Bachelor of Science degree program participate in a health innovation exhibition in which they work collaboratively in small teams to identify a real-world health care problems, generating solutions, and pitching their idea in a public on-campus event to their peers, faculty and administrators. Graduate students pursuing an Advanced Nursing Practice with a concentration in Innovation Leadership (a hybrid on campus/online format) are trained to lead change in systems, organizations, and practice environments by using innovation theories and methodologies. The program includes mentorship and a practice-oriented final project. Ph.D. degree students learn theoretical, methodological, and analytic approaches to nursing and healthcare innovation.
- *Dell Medical School, in Austin, Texas.* During the third year, students can create individualized experiences, which include starting a business or lab research, to further their own particular career and passion goals. These initiatives are also meant to introduce new ideas into the Austin community. The school provides support and mentorship. This third “Growth Year” also provides students an opportunity to obtain a second degree in public health, business administration, biomedical engineering or educational psychology.

Selected MedTech and BioEngineering Innovation Education Programs: U.S. and Europe

MedTech, biologic, and life sciences programs are leading the charge toward the type of interdisciplinary, collaborative work in health care innovation that GENiE supports. Experts, along with their students in medicine, engineering, science, and industry, are coming together to find innovative and cost-effective diagnostic tools, therapies, vaccines, and more.

These programs are not typically confined to one academic department or school; instead, they span a web of organizations and spur the creation of research centers, institutes, and innovation zones. Typically, they form vital partnerships with industry, both local and international, and have developed relationships to private and public funding sources. Students, especially at the graduate level, work closely with expert faculty and industry leaders on real-world challenges and solutions.

Notable examples of these programs are:

Duke University

Department of Bioengineering (BME) The Duke University Department of Bioengineering has become the second largest graduate program at Duke and the largest undergraduate major in the Pratt School of Engineering. The department's

close proximity to the Duke University Medical Center has fostered a highly interdisciplinary approach to research, with engineers working closely with both biological scientists and physicians. Major research programs include biomechanics, biomolecular and tissue engineering, electrobiology and neuroengineering, and biomedical imaging.

In partnership with the Pratt School of Engineering, Duke University also offers a number of specialized degree programs that support health care innovation via joint training in medicine and engineering. All programs offer extensive interdisciplinary team learning, mentorship, and real-world problem solving:

- *Medical Scientist Training Program (MSTP)* Leading to both the MD and PhD degrees, the MSTP trains highly qualified medical students as physician-scientists. The program is offered through Duke's School of Medicine and Graduate School; PhD training may be pursued in biomedical engineering or another engineering discipline through the Pratt School of Engineering.
- *MD-MEng Joint Degree Program* Designed to train "physician-inventors," this program enables MD candidates with the Duke University School of Medicine who have strong interests in health care, engineering, and innovation and entrepreneurship to earn a Master of Engineering degree from the Pratt School of Engineering.
- *InnovateMD* The InnovateMD program provides Duke residents and fellows with the opportunity to collaborate with engineering students and faculty in the field of medical device innovation. The program combines project-centered experience with supplemental learning activities.
- *Integrative Bioinformatics for Investigating and Engineering Microbiomes (IBIEM)* IBIEM was established in late 2015 to bring together scientists with an interest in microbiome research. A partnership between North Carolina A&T State University and Duke University, the program is supported by a \$3 million National Science Foundation Research Trainee grant. Graduate students in microbiology, engineering and other empirical sciences are cross-trained with theorists, model builders, and computational scientists. Formal training is augmented with workshops and an annual symposium. In addition, IBIEM trainees are exposed to and develop a range of soft skills, and are engaged with the community through outreach activities.
- *Duke Clinical and Translational Science Institute (CTSI)* CTSI is an academic hub for accelerating the translation and implementation of scientific discoveries into health benefits for patients and communities. CTSI collaborates with nearly 20 schools, departments, centers, and

programs across Duke to overcome the bench-to-bedside obstacles in developing discoveries into devices, drugs, or therapies to improve health. In 2006, Duke was awarded one of the first Clinical and Translational Science Awards from the National Institute of Health and it was renewed in 2013, committing a total of \$47 million over 5 years. The awards are given to institutions to create academic homes for translational research.

- *MEDx (Medicine + Engineering at Duke)* MEDx was forged in 2015 to enhance existing ties and foster new interdisciplinary collaborations between the School of Medicine and Pratt School of Engineering. MEDx's goal is to foster the exchange of ideas and create research opportunities between physicians, engineers, computer scientists, researchers and innovators. Its mission is to promote the training of the next generation of researchers and clinicians to work symbiotically on new solutions to complex clinical problems. Strategic commercialization opportunities to translate research advances into effective devices, therapeutics, and care delivery systems are also in the works.

Harvard University and Massachusetts Institute of Technology

- *Institute for Medical Engineering and Science (IMES)* IMES is a hub that brings together the community of students, postdoctoral fellows, and faculty who work at the convergence of engineering, science, and translational medicine. Experts in medical device, imaging, computation, big data, regenerative medicine, drug delivery, and technology transfer partner with local area hospitals and industry.
- *Harvard-MIT Program in Health Sciences and Technology (HST)* HST brings together the Massachusetts Institute of Technology (MIT), Harvard Medical School (HMS), Harvard University, and Boston area teaching hospitals in a unique collaboration that integrates science, medicine, and engineering to solve problems in human health. For over 40 years, HST has offered innovative academic programs to educate outstanding minds and cultivate future leaders in biomedical engineering, medical sciences, and clinical medicine. Over 300 students earning MD, PhD, or MD-PhD degrees train side-by-side at HST, with more than 100 affiliated faculty members guiding these students into careers as medical pioneers. HST's interdisciplinary approach to biomedicine leads to innovations, such as the drug regimen that transformed HIV/AIDS into a treatable disease and the first noninvasive technology for observing the brain in action.
- *Medical Engineering and Medical Physics (MEMP)* MEMP is a five to seven year program that leads to a PhD awarded by MIT or by the Harvard Faculty of Arts and Sciences. The program trains students as engineers or

physical scientists who also have extensive knowledge of the medical sciences. The MEMP curriculum includes multiple components that prepare students to be medical innovators. Students receive a thorough graduate education in a classical discipline of engineering or physical science, become conversant in the biomedical sciences through coursework, and engage in immersive clinical experiences where they acquire a hands-on understanding of clinical care, medical decision-making, and the role of technology in medical practice. Two seminar classes help students integrate science and engineering with medicine and develop professional skills. Neuroimaging and Bioastronautics are two areas of specialization within MEMP for which HST offers specially designed training programs.

- *Solving Clinical Challenges with Mechanical and Electrical Engineering* Since 2004 this course has brought together Boston-area physicians and MIT engineering students in developing new medical devices. Physicians present their particular challenges and then student teams work with them during the course of a semester to develop solutions. Projects identified to have a significant impact on a viable market may be continued into the spring term for the next level of implementation.
- *The Medical Electronic Device Realization Center (MEDRC)* MEDRC has as its mission transforming the medical electronic device industries to revolutionize medical diagnostics and treatments, bring health care directly to the individual, and create enabling technology for the future information-driven health care system. Specific areas that show promise are wearable or minimally invasive monitoring devices, medical imaging, laboratory instrumentation, and the communication of data from these devices and instruments to health care providers and caregivers.
- *Wyss Institute for Biologically Inspired Engineering* The Wyss Institute uses biological design principles to develop new engineering innovations to improve and transform medicine. Their “innovation funnel” enables collaborations between academics who generate innovative technologies, experts in product development, a business development team, and intellectual property experts. Entrepreneurs-in-residence drive commercialization through industrial partnerships and the creation of start-ups. Major focus areas include bioinspired robotics, 3D organ engineering, and living cellular devices.

Stanford

A joint department between the Schools of Engineering and Medicine, the bioengineering program for undergraduates and graduate students combines engineering and the life sciences with the aim of innovating advances in health care

and medicine. Synthetic biology, precision control and measurement, genomics, big data and machine learning are areas of focus. Affiliated departments and programs provide a variety of opportunities and resources for students to grow their ideas and achieve their goals. Within a 50-mile radius of Stanford's campus, there are over 500 life-sciences companies, ranging from start-ups to corporate giants. Additionally, Sand Hill Road, which borders the campus, is the "capital of venture capital" in the U.S., with a large number of firms that specialize in biotech and med tech investments. The program draws on mentorship and community expertise for issues such as patent law, FDA regulation, Medicare, and other areas of technology. Corporate members can attend annual meetings and research symposia, receive topical reports and publications, and conduct individual meetings with researchers.

- *Biodesign Innovation: Concept Development and Implementation* This two-quarter course sequence teaches students how to take a medical device invention forward from early concept to technology translation and development. Topics include prototyping; patent strategies; advanced planning for reimbursement and FDA approval; choosing translation route (licensing versus start-up); ethical issues including conflict of interest; fundraising approaches and cash requirements; essentials of writing a business or research plan; and strategies for assembling a development team.
- *Medical Device Innovation* Students learn about the variety of factors that shape or prevent health care innovation. Hands-on design projects enable students to invent their own solutions to clinical needs. Guest instructors include engineers, doctors, and entrepreneurs.
- *Bio-X* Founded in 1998, Bio-X brings together doctors, scientists, engineers, physicists, social scientists, and others to collaborate under one roof. (Nearly 700 faculty are affiliated.) In addition to modern lab space, Bio-X provides seed grants, graduate fellowships, and venture funds to drive early-stage research and educate a new generation of interdisciplinary scientist-leaders. Acting as an incubator, Bio-X fosters a collaborative culture and provides resources to explore ideas considered too experimental for federal funding.

University of Alabama:

- *The Master of Science in Biomedical Engineering (MSBME)* MSBME prepares students for entry into the doctoral program, biomedical industry, or professional school. Primary research areas include biomedical imaging, biomedical implants and devices, cardiac electrophysiology, multi-scale computational modeling, tissue engineering and regenerative medicine. Other research opportunities are available through on-going collaborations with the UAB Medical and Dental Schools. In a thesis-based M.S. degree, an individualized curriculum is developed for each student to ensure in-depth knowledge of both quantitative methods and human physiology. Public

presentation and defense of a written thesis embodying the results of student's research is required, as is publication or submission of at least one original research article in a peer-reviewed journal in which the student is expected to be the first author.

- *Master's in Biomedical Engineering with a Certificate in Technology Commercialization and Entrepreneurship* This graduate training program features collaboration between BME and the UAB School of Business. Biomedical engineering principles are blended with business-model planning in an effort to equip students to not only become scientists and researchers, but also capable business professionals. BME students partner with MBA students to turn biomedical devices into commercial products. They participate in the Invention to Innovation activities, in which they pitch their start-up companies and enter a business plan competition with the state-wide Alabama Launchpad. In addition to the BME requirements, students in this program take many hours of MBA coursework.
- *Master of Science in Biotechnology* Classroom instruction and practical training educate students about applied technology's role in the diagnosis, management and treatment of human disease, and about developing products to solve problems for present and future generations. A three-semester, multi-disciplinary program promises to teach students how to take scientific ideas from bench to business and from the classroom to the boardroom. The program's goal is to provide a direct route to a career in biotechnology by focusing on mastering current techniques used in biotechnology coupled with the business fundamentals necessary for successful product/technology development in the industry.
- *The Center for Genomic Medicine* The Center of Genomic Medicine was developed as a collaborative partnership of the University of Alabama at Birmingham School of Medicine and the HudsonAlpha Institute for Biotechnology, with a primary mission of conducting research in genomic medicine and facilitating translation of research findings into clinical practice. In support of this mission, the Center brings together multidisciplinary teams from both institutions, comprised of physicians, clinicians, biotechnologists, geneticists, bioinformaticists, and other specialists who engage in collaborative research focused on genomic discoveries that will enhance and inform patient care. The Center also offers a series of educational programs and resources in genomic medicine designed specifically for scientists, clinicians, and researchers. In addition, the Center provides a range of expertise and resources to clinicians and others interested in research and the integration of genomics into medical practice.

- *College of Public Health* The Arizona Clinical and Translational Research (ACTR) graduate certificate program offered through the College of Public Health has trained clinical investigators since 2001 and as of this date has graduated 35 students. The training includes the “Find a Mentor Program” where students can choose from about 50 mentors, which include physician scientists, social scientists, ethicists, economists, as well as experts in business and management.
- *Arizona Simulation and Technology Center (ASTEC)* Through ASTEC, the University of Arizona College of Medicine has pursued the mission to reduce preventable errors in health care by providing realistic medical training using low and high-fidelity simulation mannequins, trainers, and artificial tissue models. Modules simulate procedural work with neonatal patients, soft tissue, laparoscopic training, labor and delivery, neurosurgical, and others. Training is provided to medical students, residents, in-hospital providers, first responders’ organizations, and community members. ASTEC’s industry collaborations include Children’s Hospital of Philadelphia and Banner Medical Center, where they are developing an *in situ* simulation curriculum for management of pediatric patients with congenital heart disease. Community outreach includes ASTEC’s display of ASTEC’s 3D printing technologies for creating medical simulation training modules and artificial tissue models at local STEM events for high school and college students. Students are invited to learn to suture using a suturing pad made from artificial tissue and a custom-made chassis.
- Financial support from the University of Arizona IT Student Advisory Board has enabled ASTEC to open an Innovation Zone in the College of Medicine for a 3D printing laboratory to promote collaborative work between the Colleges of Engineering and Medicine. New training modules include ultrasound-guided pericardiocentesis; umbilical venous catheter model; pediatric chest tube chassis; and a microsurgery tool kit for practicing microsurgical techniques.

University of Copenhagen

- *Biomedical Engineering* Biomedical Engineering is an interdisciplinary program offered by DTU in collaboration with the Faculty of Health and Medical Sciences at the University of Copenhagen. The program aims to educate MSc students in the real-world health care problems and motivate them to develop technological solutions. Students study both engineering and human physiology and design an individual thesis project. The innovation environment includes many international research groups in ultrasound imaging, magnetic resonance, positron emission tomography,

biomechanics, hearing aids, image interpretation, biomedical signal processing, brain computer interface, cellular signaling, and more.

- *Centre for Medical Science and Technology Studies* The Centre for Medical Science and Technology Studies is a collaboration between scholars in the Unit of Health Services Research, Department of Public Health, and the University of Copenhagen, and is affiliated with the Center for Science, Technology, Medicine & Society, University of California–Berkeley and Medical Humanities Sheffield at the University of Sheffield.
- *Biotech Research and Innovation Center (BRIC)* BRIC was established in 2003 by the Danish Ministry of Science, Technology, and Innovation with the goal of performing interdisciplinary, cutting-edge research, attract funding and new research projects that contribute to innovative product development, and promote exchange of ideas within the Danish biotech research community. Graduate students at BRIC work on innovative, independent research projects with the support of mentors, modern laboratory facilities, and an environment of international research and study.

In fall of 2013, BRIC joined EU-life, an alliance of top research units in life sciences. This union provides access to a large European network, new collaborations, sharing of knowledge and core facilities, research visits and career building possibilities. The goals of the BRIC–EU-life partnership are to promote excellence in research, promote integration among European research institutes in life sciences, develop and share best practice in research, research management and training, to attract and integrate talents, and to favor mobility within Europe.

University of Pennsylvania

- *Department of Chemical and Bioengineering* University of Pennsylvania claims to be the first to offer a doctorate degree in bioengineering in the U.S. (1953). Penn Bioengineering links faculty from the engineering, medical, and arts and sciences schools on a centrally-located campus. Students work in a collaborative culture that includes leaders in academia, government, and industry, and are carefully matched with faculty-mentors based on their research interests. Projects involve observing and manipulating living systems from the small (molecular) to the large (physiome), with the aim of innovating technology to better understand fundamental biological processes and improve clinical practice and patient care. Much of the research capitalizes on university ties with clinicians, enabling the translation from bench to bedside.

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