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Educational Commentary

Cultivating Physician-Engineers as Clinical Innovation Influencers: The Medical Innovators Development Program (MIDP)

The number of transistors and resistors on a chip doubles every 24 months.
— Gordon Moore.

Every body continues in its state of rest, or of uniform motion in a right line, unless it is compelled to change that state by forces impressed upon it.
— Isaac Newton.

INTRODUCTION

Resistors on a chip have a pattern of innovation. However, just as mountains do not like to be moved, the health care industry—intentions and altruism aside—is often a large, resting force. New ideas are often bridled in clinical settings by a culture of complacency, overwork and inertia that creates a chasm between engineering development and clinical adoption with no pattern of innovation. Some of the main barriers include culture, reimbursement, and competing stakeholders. This is not at the individual level but there are complex systems that make it difficult to promote change.

Substantial obstacles to innovation are that healthcare providers and patients are typically comfortable with the status quo, and may have negative experiences with prior change. For example, introducing innovative health information technologies and electronic health record systems into clinical practice is commonly considered a barrier to efficient and high-quality healthcare delivery.[3] In contrast, a clinical practice that is ready for change has a culture that looks for ways to improve; and promotes and supports ways to enhance quality, patient care, and efficiency. There is a need to overcome the existing chasm that results in poor adoption to change. The ability to change is crucial to the success of any organization and has never been more important than it is in today's changing practice environment. Diffusion of innovation requires a well-adapted team of influencers that share a common ''why'', despite the differences in the ''what'' and the ''how''.[5]

The ''convergence'' of engineering, physical and computational sciences with biomedical and life science creates a synergy that can transform innovation as a new praxis and culture in healthcare.[4] This idea has motivated the development of academic-based interdisciplinary healthcare innovation programs. Notable examples include Stanford Biodesign and hospital-based programs such as The Healthcare Transformation Lab at Massachusetts General Hospital. However, according to the Convergence: The Future of Health report,[4] true convergence education models ''require considerable funding, teaching and research teams that cut across traditional disciplinary boundaries, shared physical space, and curricula that balance specialization with breadth of knowledge''.

From this perspective, the Vanderbilt University School of Medicine has recently introduced the Medical Innovators Development Program (MIDP) to educate and develop a cadre of clinician engineering innovators. This program's goals are to combine the students' specific areas of expertise at an advanced level with formal medical education to reinvent medicine into a clinical innovation hub that more rapidly translates technology advancements to clinical care. Candidates for the program have already completed their Ph.D. in an engineering discipline prior to applying to medical school. During the interview process for the program, the candidates engage in an innovative one-day design challenge where we are able to assess design thinking, team working ability, divergent and convergent thinking, and the ability to resolve a consensus solution.

We are creating Engineer-Physicians armed with graduate level engineering principles and education on systematic problem identification, needs assessments and solution. They are being armed with advanced design thinking geared towards solving healthcare problems as they also learn differential diagnosis. The medical training offers a deep biomedical science exposure and an absolute and necessary connection to the role of treating physician. They are also being armed with the history of medicine encompassing medical humanism, a feature that cannot be learned in design school or a brief exposure to medicine that the Ph.D. postdoctoral scholar might gain from doing translational research.

At its core, the MIDP is designed to accelerate innovation into the flow of clinical practice by training students to be activists. This innovation activism requires the students to effectively bridge the domains

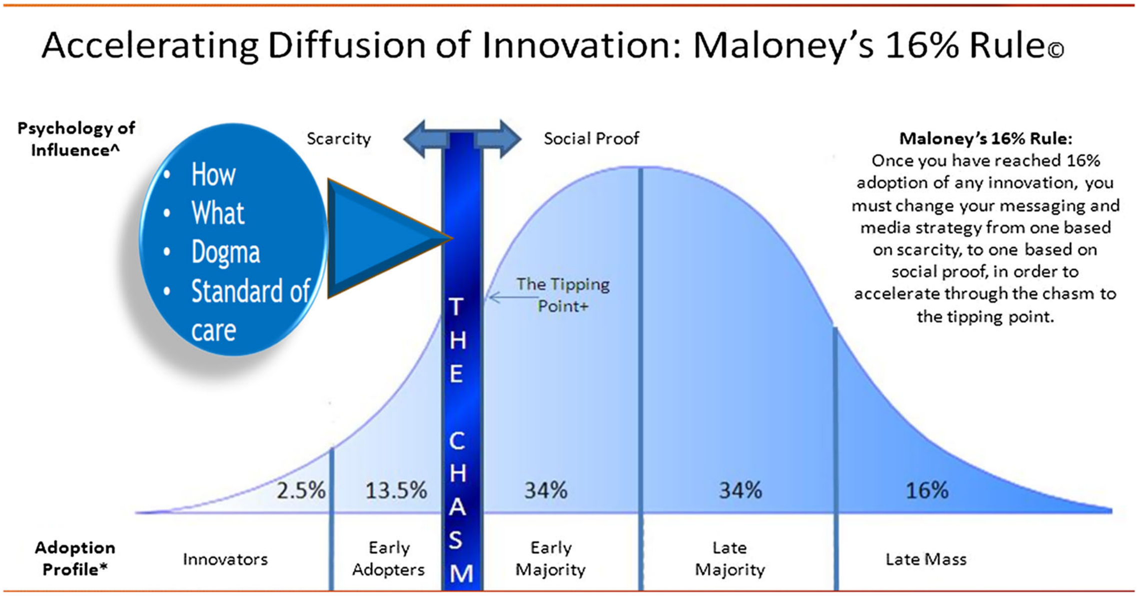

FIGURE 1. Diffusion of innovation curve. The clinical chasm exists for many reasons, including differences in domain language, dogma, standard of care and others.

of engineering, design, and biomedicine. Innovation activism builds on the model that all systems can be improved, and it is not simply for the sake of innovation, when patient focused care is embedded. Another arm of innovation activism is training students to be influencers and thought leaders with a strong understanding of how to enhance adoption of technological improvements into the clinical flow. The resulting vision will be communicated to everyone in the practice and continually reinforced to foster a culture that is ready for the changes needed to advance clinical practice.

These students are trained to see beyond the standard of care, to the standard of excellent care. We are working to shift the diffusion of innovation curve, turning the early majority into the early adopters. Engineers embedded as clinicians in the clinical flow will have equal push and pull, transforming technology adoption into the innovation birthing phase[5] and hence closing the chasm (Fig. 1).[2]

THE CURRICULUM

Vanderbilt University School of Medicine provides a unique environment to cultivate the development of such a transdisciplinary educational model. The school's Curriculum 2.0 offers the opportunity to develop and integrate specialized material and content within the MD traditional training program. This is possible through personalization (within prescribed guidelines) of each student's coursework in the third and fourth years. In addition, the integrated Vanderbilt campus which includes the School of Medicine, The Vanderbilt Hospital, The Monroe Carell Jr. Children's Hospital at Vanderbilt, the School of Engineering, the Owen Graduate School of Management and the Vanderbilt School of Law all located on a compact footprint facilitates close collaboration between faculty and students of all schools.

In the first year of medical school, the MIDP students follow the path of the traditional MD students, with the addition of the MIDP Forum where they are exposed to leaders in the innovation space, to the basics of "needs-storming" and preparation for design thinking (Fig. 2).

In the second year of medical school, while participating in the clinical clerkships as traditional MD students, MIDP students are tasked to think of engineering at the intersection of science and society. Engineering Grand Rounds is grafted into these clinical clerkships where the students consider technical aspects of the patient interaction while they are on clinical rotations (Fig. 3). This engagement creates the "science friction" that requires an understanding of patient, clinician, and system along with how to integrate engineering processes or product considerations into the clinical environment. Through instruction from faculty from the School of Engineering, this is formalized by the development of the Clinical Quality Functional Deployment (CQFD). In the CQFD, students identify concerns observed by themselves or clinical customers. Once the students have a compendium of concerns, they then correlate measurable

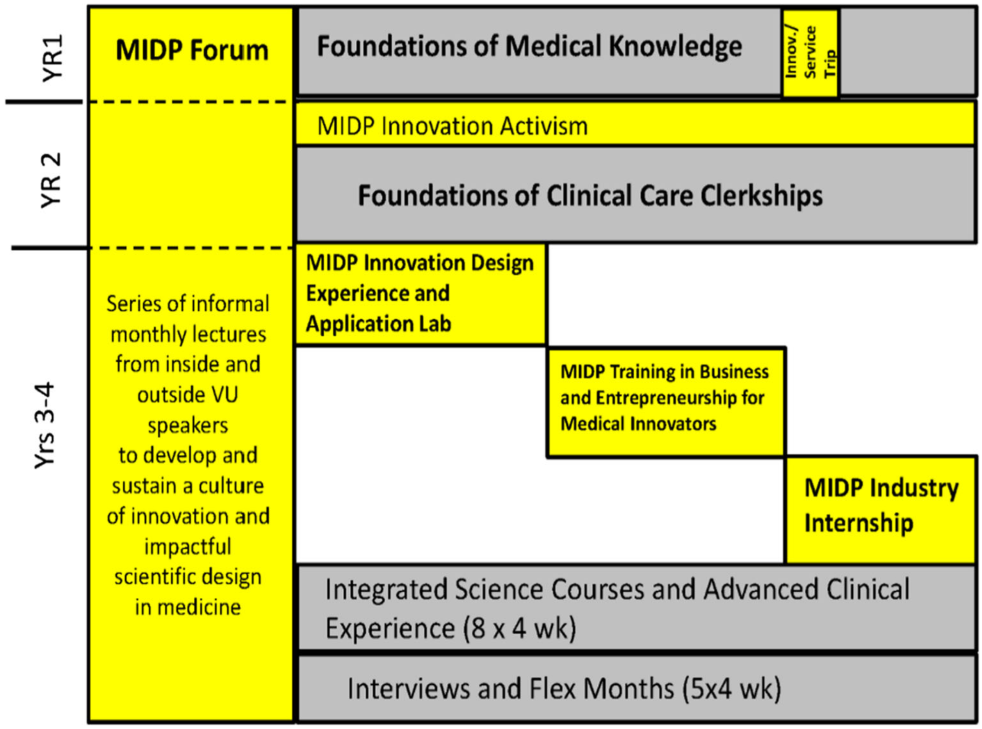

FIGURE 2. The MIDP schematic of the curriculum.

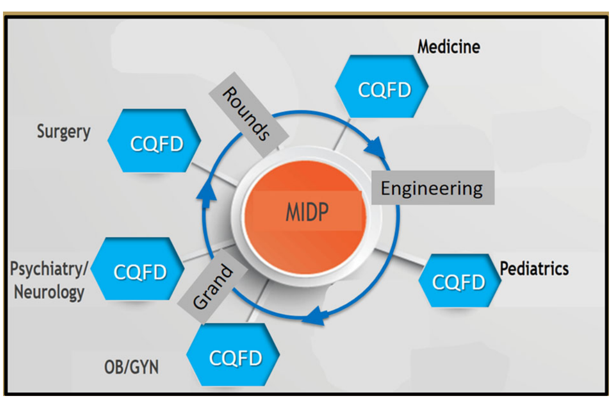

FIGURE 3. The integration of engineering grand rounds and clinical quality functional deployment (CQFD) during clinical clerkship rotations.

engineering parameters that can address these concerns. The students then score the degree to which the engineering parameters comply with the clinical concerns, thus creating a quantitative matrix of the observation experience.

The highest scoring CQFD assessments are then taken into the third year Innovation Design Experience and Application Lab (IDEA Lab). In this third year, the design and development stage-gates are executed as the students create a prototype or new process that results from the second year clerkship experience. Students collaborate and are mentored by both engineering and clinical faculty to co-develop the product or process. Finally, with the addition of instruction and advice from faculty from the Owen Graduate School of Management, Vanderbilt School of Law and local business entrepreneurs, the product or process is then taken through the regulatory, marketing, and patent incubation stage as a segue to the entrepreneurial path.

Throughout all 4 years, MIDP students engage in idea acceleration events that we call the MIDP Forum. These forums include 60-min brainstorming sessions once or twice per month, and bring together clinicians, engineers from across the campus and industry to create knowledge around the CQFD. These sessions allow for an open innovation environment to create a more robust engagement of the clinical concern developed as part of the clinical clerkships. Correlations between the measurable engineering associated parameters and the clinical customer concerns are vetted, and a consensus is made of the design direction. These sessions provide critical components of the design thinking skillsets that drive the innovation acuity needed for clinically active observation. This activity is done with sufficient rigor and consistency that the student develops a sustained intuition or ideasthesia around innovation opportunities.[1] All of these curriculum components are integrated into the standard medical education without adding years or taking away from medical training.

As leaders in healthcare delivery, medical centers can create a culture that embraces innovation to bring about change and improvements in delivering patient care. This innovation can alter and improve routine tasks where doing so brings a large relative advantage. As an innovation activist, the MIDP student becomes acutely aware of these instabilities and braces the system to increase stability. Hence, our MIDP students must be as sensitive to engineering appropriateness as they are to user appropriateness, and activists are aware of the flow of the clinical space and skilled at engineering improvements. The fuzziness of the boundaries of the innovation can impact its adoption. Specifically, innovations with a small core and large periphery are easier to adopt. Innovations that are less risky are easier to adopt as the potential loss from failed integration is lower. This is a much-nuanced balancing act that our approach to training the medical students embraces.

The clinical space provides environmental pressures on a daily basis that are rich with opportunities for innovation. The problems bubble up, but without appropriate ideators to capture, circumscribe and convert them to a design thinking process, they drift into the ether. The notebook becomes part of the design history file of the exposures to clinical environmental pressures that will transform medical centers from service only, to clinical innovation hubs. These clinical innovation hubs can usher in a movement where constant improvement becomes the gold standard. Other specific program features include:

- Innovation Service Trip—A domestic or international trip which provides experience in the impact of environment on engineering design;
- Unique interdisciplinary coursework—Elective courses covering topics such as business, entrepreneurship, intellectual property, technology transfer, Lean Start-up principles, and the Food and Drug Administration approval process for medical devices;
- Industry internship—A 2 month placement with an industrial partner designed to strengthen knowledge of academic-industrial partnerships.

THE MIDP FORUM

The MIDP Forum is intended to immerse students in a culture of innovation and to lay the groundwork for a collaborative network of innovators. No single Forum is life changing, it is the collection of all of the forums that fundamentally teaches the students aspects of innovation, failure, luck, and the uncomfortable realization that everyone they meet has gone through challenges and they are on the other side of it. Medical students are not exposed to this mindset in traditional medical education, where, unintentionally, it seems that things either (a) just happen for no reason, or (b) that they progress in an orderly logical way. An innovation/research experience shows that things do not go always the way they were planned. There is a real encouragement of a naïve optimism that others think is impossible.

In addition to Forum speakers from across Vanderbilt's campus, external speakers have included Roderick Pettigrew, Ph.D., M.D. founding Director of the National Institute of Biomedical Imaging and Bioengineering and now leading Texas A&M's EnMed program, Paul Yock, M.D., founder and director of Stanford Biodesign, and Gerald "Jerry" Wilmink, Ph.D., M.B.A., Vanderbilt biomedical engineering alumnus.

ADMISSIONS

Currently, the MIDP admissions process has two pathways to entrance. First, we consider applicants who apply to MIDP directly. Second, we also invite those VUSM M.D. applicants who hold a Ph.D. in engineering or applied science to transfer application from M.D. to MIDP. The first three MIDP students matriculated into the medical school in summer 2016. The class includes two bioengineers, and one mechanical engineer with significant industry experience. In the second year, four students matriculated in the summer of 2017, and one deferred admission to summer 2018.

We have carried out assessments that allow us to meet the interest of the candidates. In one such assessment, we have determined that there is a cadre of Ph.D. engineering graduates that would like to use their area of expertise in a clinical entrepreneurial career.

In April 2017, the first year students completed a week-long innovation service trip to Guatemala to identify opportunities where innovation can help meet global health challenges. Finally, the program is planning to host a conference of other like-minded institutions to build momentum for convergence training in medical education.

CONCLUSIONS

It is critical to identify and implement a strategy to educate the next generation of convergence physician-engineers in healthcare. The MIDP is one unique solution to this challenge. Through the deliberate integration of innovation, design, business and entrepreneurship within a medical curriculum targeted to engineering scientists, interdisciplinary collaboration in medicine can be amplified by true multidisciplinary expertise. The MIDP students are connected and committed to patient care because of their true personal connection to each patient that fuels creativity, earnestness and passion. We don't innovate for innovation sake—we innovate because of a deep connection that the MIDP/M.D. has to each patient.

While the summation of its component parts make MIDP unique, at the core the MIDP students will have a physician's soul. It is the physician training that fuels the MIDP student; otherwise they are merely technologists with an extra accreditation. To be true chasm jumpers, students should understand and speak both languages with bilingual fluency.

We look forward to witnessing our graduates go forth and make their impact in biomedicine, and working with other multidisciplinary programs with the common goal of revolutionizing medical education to meet the needs of society. We look forward to others joining us to advance the teaching of innovation/inclusion/influence of the engineering design thinking mindset to health care.

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