Science of Health Care Delivery: An Innovation in Undergraduate Medical Education to Meet Society's Needs

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Abstract

The purpose of this special article is to describe a new, 4-year Science of Health Care Delivery curriculum at Mayo Clinic School of Medicine, including curricular content and structure, methods for instruction, partnership with Arizona State University, and implementation challenges. This curriculum is intended to ensure that graduating medical students enter residency prepared to train and eventually practice within person-centered, community- and population-oriented, science-driven, collaborative care teams delivering high-value care. A Science of Health Care Delivery curriculum in undergraduate medical education is necessary to successfully prepare physicians so as to ensure the best clinical outcomes and patient experience of care, at the lowest cost.

The Institute for Healthcare Improvement's "triple aim" is to ensure optimal health outcomes with the best experience of care at the lowest cost.[1] Despite tremendous changes in the US health care system, research advances are slow to enter clinical practice, many patients lack access to care, clinical outcomes are frequently suboptimal, care is fragmented, and the current system is financially unsustainable. In addition, the many incentives built into current care delivery systems often do not align with patients' best interests. Therefore, these systems must be redesigned at every level, and leaders must provide a compelling vision and enable the diverse health care workforce to implement solutions for the patients they serve. Teams must integrate and coordinate care, share knowledge, collaborate across teams and within communities, and rapidly adopt new care models.

Since the Flexner report[2] was published, US undergraduate medical students routinely have been educated in the basic (eg, anatomy, histology, physiology) and clinical (eg, history taking, physical examination, differential diagnosis) sciences. Although many schools have added content over the years (such as evidence-based medicine [EBM], population health, and cross-cultural communication), these curricular additions often have been made in a piecemeal fashion and have not matched the pace of change in health care. To help ensure that medical education meets the needs of society in the 21st century, students must learn the third science of health care delivery,[3] also referred to as health systems science (HSS),[4] as they learn the basic and clinical sciences.[5]

In 2013, Mayo Clinic School of Medicine (MCSM), in partnership with Arizona State University (ASU) and with support from the

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Kern Family Foundation and the American Medical Association's Accelerating Change in Medical Education initiative, began work on a new model for undergraduate medical education that includes a required, 4-year, integrated Science of Health Care Delivery (SHCD) curriculum.[6] The intent of this curriculum is to ensure that graduating medical students enter residency prepared to train and eventually practice within person-centered, community- and population-oriented, science-driven, collaborative care teams delivering high-value care. The purpose of the current article is to describe the curriculum, the experience with it and outcomes to date, as well as challenges for successful completion and sustainability of its implementation.

CURRICULUM OVERVIEW

The SHCD curriculum is required for all MD students who matriculated in or after July 2015. Starting in 2017, this included full cohorts of students, on both of Mayo Clinic's 4-year campuses (Rochester, Minnesota, and Scottsdale, Arizona). The year 3 and year 4 portions of the curriculum have been designed but not yet fully implemented, as the first

cohort of students entered year 3 in July 2017. The curriculum is structured within 6 domains of knowledge: person-centered care; population-centered care; team-based care; high-value care; health care policy, economics, and technology; and leadership.[6] Leaders for SHCD were directed by their curricular deans to opportunities for enhancing time in the 4-year curricular schedule to ensure that the new curriculum did not negatively affect the time spent on basic and clinical science content.

Instruction during the first 2 years is primarily a blend of online and face-to-face activities, with 74 online modules providing knowledge and assessing understanding of key concepts before activities are undertaken in the classroom or simulation center. Interactive classroom experiences include informal simulation, case-based discussions and reflections, dialogue with subject matter experts, and panel and student presentations. Longitudinal curricular experiences (known as "threads"), with substantial preclinical and planned clinical activities (shared decision making [SDM], health coaching, and high-value, cost-conscious [HVCC]) care, help ensure that what is learned in the first 2 years will be successfully practiced and applied during the clinical years.

Figure 1 indicates the SHCD content in the 4-year curriculum. Roughly half of the curricular content is delivered in two 2-week blocks. Approximately 20 hours of content is delivered after step 1 of the US Medical Licensing Examination, as part of students' preclinical multispecialty block. Two weeks of instruction are planned for midway through year 3 and 1 week during March of year 4. All graduating students earn a Certificate in the Science of Health Care Delivery, and students who opt to complete additional credits can earn a Master of Science degree in the Science of Health Care Delivery from ASU as part of their 4-year undergraduate medical education program.

Once the SHCD curricular framework was created and consensus learning outcomes were written for each domain (Table), a curriculum team was selected to be responsible for curriculum development, implementation, student assessment, and ongoing improvements. Because this national school (with campuses
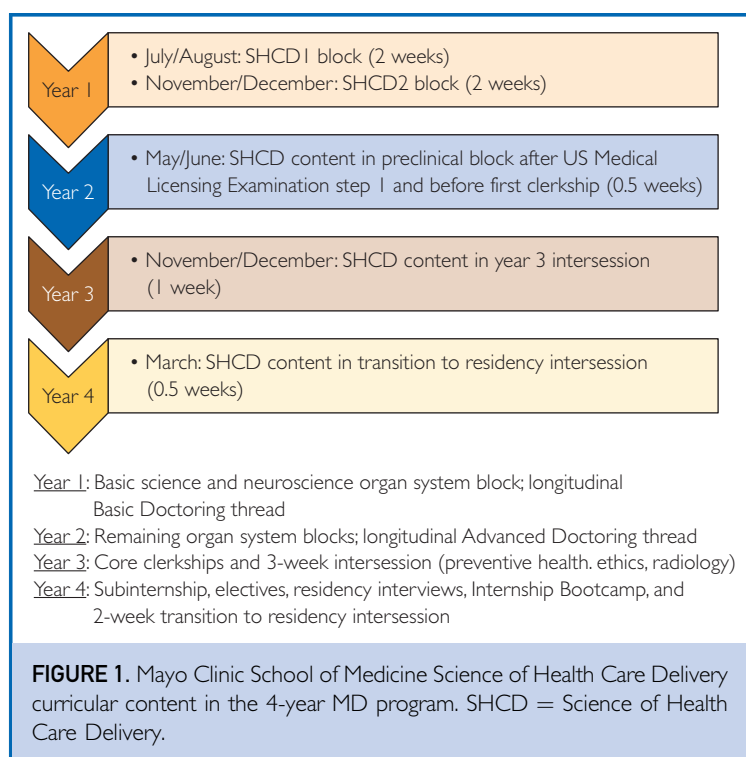

FIGURE 1. Mayo Clinic School of Medicine Science of Health Care Delivery curricular content in the 4-year MD program. SHCD = Science of Health Care Delivery.

TABLE. Mayo Clinic School of Medicine Science of Health Care Delivery Curricular Learning Outcomes by Domain

Domain	Learning outcomes
Health Policy, Economics, and Technology	• Summarize key principles of health care economics • Describe the development of US health care policy • Analyze current US health care policy and its impact on how care is delivered and financed • Describe the role of clinical informatics, health care information technology, and technology assessment in improving patient outcomes • Describe US health law and compliance and implications for the delivery of patient care
High-Value Care	• Form clinical questions and retrieve/appraise/assimilate evidence from scientific literature to provide high-value care (for individuals and populations) • Identify system failures and errors and advocate for a culture of safety and practice improvement to provide high-value care • Provide high-value, cost-conscious care to individual patients and suggest strategies for such care for populations of patients
Leadership	• Develop and describe a single vision for health care of the future • Summarize and reflect on strengths and areas for growth with regard to one's individual leadership traits and skills • Summarize key leadership principles for health care
Person-Centered Care	• Describe and apply strategies and best evidence for personalizing care for individual patients • Describe and effectively use best evidence and techniques (motivational interviewing, coaching) for assessing and counseling patients regarding healthy lifestyles (including behavioral aspects of health) • Effectively communicate and negotiate across cultures, languages, life spans, and literacy levels • Develop skills in advocacy theory, execution, and communication to promote person-centered care
Population-Centered Care	• Describe the health system's role in improving the health of a population of patients • Describe key concepts in population health: regulatory drivers of population health, emerging strategies and tools for improving population health, prevention and health promotion, and the role of community engagement and resources to support population health • Recognize and apply population surveillance gaps in processes and outcomes of care
Team-Based Care	• Demonstrate effective teamwork in classroom and clinical settings • Demonstrate effective team-based, person-centered care • Describe the characteristics of high-performing teams • Demonstrate the ability to effectively provide and receive patient handovers for transition of care responsibility

in Minnesota, Arizona, and Florida) has two 4-year campuses (first Arizona cohort matriculating in 2017), each of the 6 teams includes a Mayo Clinic physician from Minnesota, one from Arizona, subject matter experts from MCSM and ASU, and an ASU instructional designer. Each domain of the curriculum is summarized in the following sections, with specific examples of educational strategies that are used within the domain.

Health Policy, Economics, and Technology

The Health Policy, Economics, and Technology domain content includes the following:

- Basic health economics (basics of health economics and how it differs from general economics; competitive market modeling)
- Health care policy (historical overview of American health care policy; requirements of a health care system; health insurance;

public policy development; the American health care workforce; comparative health care policy; practice variation) and

- Clinical informatics (introduction to clinical informatics, health information exchanges, clinical decision support systems) and research informatics.

Much of the domain's curriculum is presented to year 1 and year 4 students, with 2 hours of classroom time between years 2 and 3. Students engage in classroom discussions on policy advocacy, increasing consumer awareness in health care, growing price transparency in medicine, an overview of yearly US health care expenditures, and the pros and cons of market-specific integrated delivery systems. In year 4, content on law and medicine is also presented, including health law and compliance, professional liability, and regulatory law.

High-Value Care

The High-Value Care domain focuses on the "value equation": quality divided by total cost of care over time, where quality can be further defined as the sum of clinical outcomes, patient safety, and service (patient experience).[7] The domain's content includes the following:

- Critical appraisal of the literature for clinical application (EBM)
- Health care improvement (patient safety, quality improvement, analyzing systems errors, diagnostic errors) and
- HVCC care (ie, balancing quality with cost).

Students first learn foundational core concepts (eg, "thinking value"). These include perspectives on health care value from various stakeholders, the Institute of Medicine (now National Academy of Medicine) dimensions of quality,[8] Just Culture,[9] levels of the health care system, and high-reliability organizations. The sequence of topics is shown in Figure 2.

The principles of EBM (basic medical statistics and epidemiology for clinical practice) are taught in year 1, along with a more intensive EBM workshop at the end of year 2 before the clinical clerkships. This longitudinal curriculum requires completion of several "critically appraised topics" through the clinical rotations in years 3 and 4. In year 3,

students apply quality improvement methods and tools and learn the Institute of Medicine framework for identifying diagnostic errors,[10] after which they identify ways to minimize these errors in clinical cases. In the classroom, students use concepts from human factors, systems engineering, and informatics to analyze a patient safety—related event.

Principles of HVCC care are learned using the 5-step framework published by the Alliance for Academic Internal Medicine and the American College of Physicians.[11] The steps are as follows:
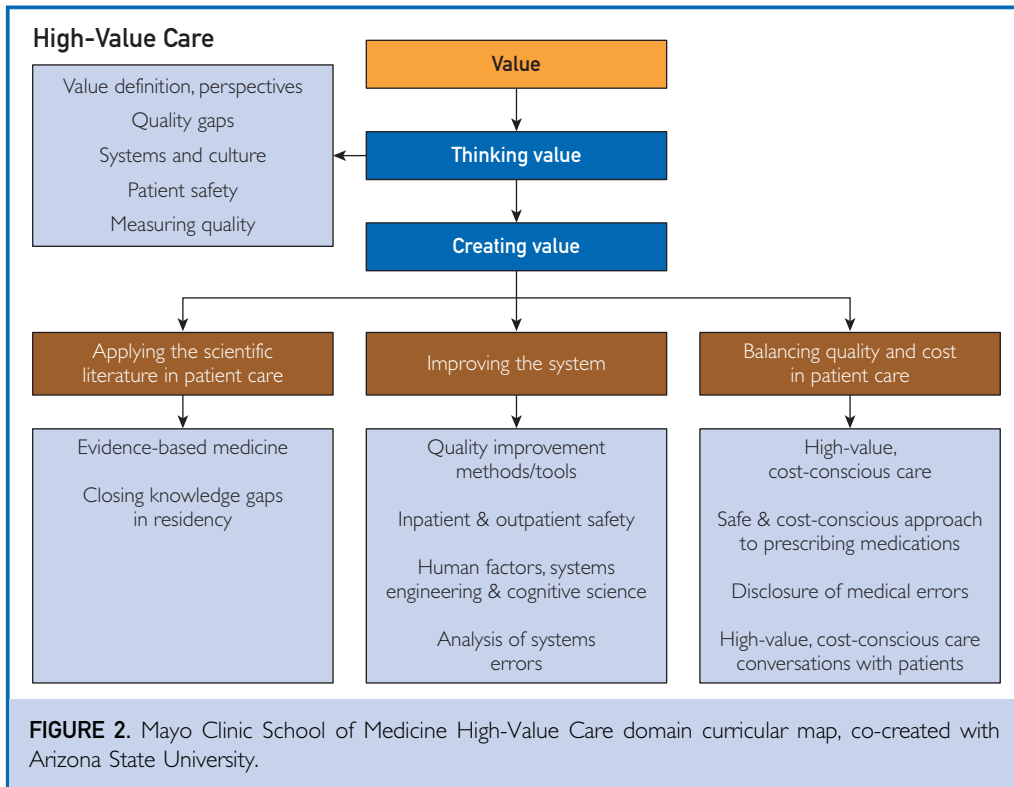
Step 1: Understand the benefit/harms/relative costs of interventions

Step 2: Decrease/eliminate use of low- or no-benefit interventions

Step 3: Choose interventions that maximize benefits, minimize harms, and reduce costs

Step 4: Customize care plans with patients

Step 5: Identify system-level opportunities to improve outcomes, minimize harms, and reduce health care waste (ie, health care improvement)

The importance of appraising the medical literature through EBM is stressed, along with facilitating HVCC care, physician-patient conversations (eg, "less-is-more" conversations and SDM based on patient preferences and values). Students complete the curriculum known as SOAP-V (for subjective-objective-assessment-plan value)[12] just before starting their clerkships to help ensure that they are more likely to raise issues of health care value on rounds. Midway through year 3, students share their successes and challenges with their colleagues and faculty by bringing health care value topics to their clinical teams. Students also complete a checkbook exercise or retrospective review of charges for a hospitalized patient they have cared for during a clerkship.[13]

Leadership

The Leadership domain content includes the following:

- Leadership traits
- The importance of openness to feedback for self-improvement, and

FIGURE 2. Mayo Clinic School of Medicine High-Value Care domain curricular map, co-created with Arizona State University.

• Principles of management (developing a vision, change management, engagement across boundaries, understanding and shaping culture, engaging teams, earning the right to leadership, and strategic planning).

To develop leadership traits, students discuss their personal values and the importance of aligning these values with the organization in which they work, as well as standards of professionalism, ideal behaviors, and potential pitfalls for accomplishing these behaviors. Students take an emotional intelligence survey, receive their results confidentially, and then participate in a half-day, interactive session to learn what the results mean and how they can use them to change their behaviors. The interactive session focuses on self-awareness, self-management strategies, social awareness, and relationship management.

In year 3, students have a 360-degree review to give them input from peers and faculty on their leadership skills and behaviors. Faculty advisors confidentially review

these evaluations with the students and provide coaching to improve concerns about leadership skills. Advisors who want more training can participate in a program on leadership coaching to assist them in becoming effective at communicating and enhancing leadership behaviors. To improve their skills, students practice leading a simulated multidisciplinary team on hospital rounds.

Person-Centered Care

The Person-Centered Care domain focuses on ensuring that graduating students learn skills that will enable them to provide person-centered care to every patient. The domain's content includes the following:

• Personalizing care, including SDM[14]
• Minimally disruptive medicine,[15] motivational interviewing, and health coaching
• Physician-patient communication skills beyond those traditionally learned in clinical science, and
• Physician roles in advocacy.[16]

Students are introduced to the concepts of SDM and minimally disruptive medicine in year 1 through online modules, interactive classroom activities, and a longitudinal experience (threads). They learn key concepts of motivational interviewing, with emphasis placed on the "OARS" process of using open-ended questions, affirmations, reflective listening, and summary statements. Students learn several strategies for wellness promotion and behavior change from a certified patient health and wellness coach who has a background in counseling psychology. Students practice what they have learned by coaching each other on their individual wellness goals. Several key concepts for effective communication are taught, including teaching and "teach-back," at appropriate levels of health literacy. These communication skills are linked with several ongoing activities in which students learn and refine medical interviewing skills via a cultural humility classroom workshop and a cross-cultural communications simulation, using standardized patients.

As an example, in the first 2 weeks of year 1, students are introduced to patient advocacy by having them collaborate to suggest ways of advocating for individual patients and populations of patients with regard to a specific health issue. In small groups, they complete a "day-in-the-life" activity and try to "walk in the shoes" of a fictional patient (such as a new immigrant who has diabetes mellitus, limited English-speaking skills, and transportation challenges). Students then travel to 3 or 4 local community health partners (eg, a food bank or public health department) to learn each agency's role in the health of individual patients and groups of patients, and they submit a written "reflection" assignment about what they have learned.

Population-Centered Care

The Population-Centered Care domain focuses on developing the knowledge base and skills necessary for graduates to improve health outcomes for groups of patients (population health).[17-19] This domain's content includes the following:

- Population health basics (health care disparities; access to health care and the social determinants of health; comparisons among population health, public health, and population medicine; community engagement; and cultural competence)
- Regulatory drivers for the population health focus in health care delivery
- Strategies and tools used to identify and care for patient populations (health information technology, new types of health care workers, and team-based care)
- Prevention and health promotion activities to prevent disease and maintain health, and
- Role of community engagement and resources to support health needs.

In their first 2 weeks of medical school, the students complete their "PIVoT" experience—person-centered, population-oriented, inter-disciplinary, high-value, team-based care. During this afternoon session, students are assigned to a clinical microsystem to follow a patient's progress and learn how each member of the health care team (registered nurse, licensed practical nurse, care manager [registered nurse], clinical assistant, social worker, provider, secretary) adds to the clinical encounter and delivery of patient care. In this way, students are exposed to processes, strategies, and tools that improve care of individual as well as groups or populations of patients. Students learn about disease prevention and health promotion just before their clerkships (end of year 2). In year 3, students practice basic analytic skills using databases (eg, hospital, clinic, and insurance registries; regional, state, and national epidemiologic databases) that can help characterize populations to determine health care needs, as well as determine outcomes of interventions.

Improving population health has received increasing attention in health care delivery, in part because of the "triple aim" and new health policies focused on specific patient populations. For example, the numbers of elderly patients and those who have chronic diseases are increasing in the United States, with correspondingly poor health outcomes relative to the high cost of their care. Vulnerable populations may face challenges relating to access to care and may be particularly affected by social determinants of health, with resultant poor health outcomes. Understanding the needs of patient groups and practicing population health can make a

substantial difference in improving health care delivery and decreasing costs of care.

Team-Based Care

The Team-Based Care domain focuses on developing the skills physicians need to be effective in an integrated, multidisciplinary, health care system. The content is organized by the following concepts/skills practice needed before and during the core clerkship, respectively:

- Effective communication, mutual support, situational monitoring, servant leadership, team structures and roles/responsibilities (before), and
- Clinical rotations and simulation (during).

Team structures with defined roles and responsibilities are taught and practiced using simulated scenarios in various patient care contexts and with increasing levels of complexity, diversity, and stress (eg, cognitive, emotional, sociocultural, ethical, and/or financial). Students learn to understand and appreciate various personality types, including their own, and how each type can positively contribute in a team setting. The importance of effective communication across teams is emphasized through classroom exercises based on the program known as TeamSTEPPS for team strategies and tools to enhance performance and patient safety.[20] Students learn the framework known as SBAR, for its use of situation, background, assessment, and recommendation,[21] and the system for patient handover known as I-PASS, for illness severity, patient summary, action list, situation awareness and contingency planning, and synthesis by receiver[22] and their use in clinical microsystems.

During their year 3 clerkships, students deepen their understanding of team-based care, in part through reflection on their own experiences. In addition, they participate in structured, interdisciplinary, team-based simulations designed to improve team skills in 5 specific scenarios, including a primary medical home, an outpatient clinic, an inpatient setting, a poly trauma setting, and leading rounds. Students will have the opportunity to review and assess their recorded performance and receive appropriate coaching and feedback from instructors.

EDUCATIONAL METHODS

Blended Learning

Blended learning, or a "flipped" classroom, is a teaching approach in which learners are exposed to new content before class and then process the information in a facilitated, group setting.[23] Research has demonstrated the efficacy of this pedagogic approach in educating health care professionals.[24] This model was chosen to most efficiently leverage subject-matter expertise across all campuses and ASU for delivery at 2 sites (Minnesota and Arizona). To maximize student engagement, the content modules were designed to be approximately 45 minutes long, including all assessments and reading assignments. The SHCD domain teams closely followed the Backward Design Model popularized by Wiggins and McTighe,[25] summarized as follows: (1) determine measurable learning objectives; (2) align assessments with learning objectives; (3) align learning activities with objectives; and (4) use tools and technology. Because clinical faculty members have limited time to provide individual feedback on free-text responses in the modules, "expert" responses are provided so students can compare their responses to those of the "expert" (faculty member). Scored, summative assessments are included in nearly all modules and are supplemented with direct observation of performance in the classroom and other experiential assignments.

Each module underwent a final review in the learning management system and quality assurance testing before launch. In addition, a content-authoring tool was used to create interactive learning experiences and quizzes for the students. This tool allows for more exploration of content through directed feedback and storytelling scenarios. Short video lectures are also used in the curriculum. Although the original intent was to create online modules to support classroom instruction, the project has yielded much more in terms of technological applications, including establishment of a collaborative model for course development and a new dimension (including new processes) of technology use in medical school.

Simulation

"Simulation is the imitation or representation of one act or system by another. Healthcare

simulations can be said to have four main purposes—education, assessment, research, and health system integration in facilitating patient safety."[26] Simulation provides a safe, trusted space for deliberate reflection on and practice of SHCD communication skills and behaviors and amplifies the other experiences by requiring integration of cognitive, psychomotor, affective, and interpersonal skills while allowing for peer and faculty feedback on performance. The SHCD curriculum includes year 1 classroom simulation for skills practice (team building, interprofessional communication during health care emergencies), standardized patient scenarios for skills practice and feedback in years 1 and 2 (cross-cultural communication, patient handovers), and interprofessional simulation in year 3, focusing on team-based care and leadership skills. For example, specific skills are taught and simulated while students lead rounds. Supervising faculty will assess these skills during students' subinternship rotations.

Several important SHCD-related physician-patient communication skills are essential in HVCC care, so opportunities for students to practice these skills and for faculty to provide feedback via direct observation are needed. Ensuring that every student has the opportunity to engage patients in such conversations and that busy clinical faculty can directly observe these conversations can be challenging. In addition, role modeling among residents and faculty with respect to HVCC care conversations may be inconsistent and of varying quality.[27-29] Therefore, 2 standardized patient scenarios were developed (Natt N, Starr SR, Reed DA, Dyrbye LN, Park YS, Leep Hunderfund AN, unpublished data, 2013-2014; 2014-2015) for year 3 to provide students with formative assessment (feedback). These scenarios highlight 3 types of SHCD conversations: (1) "less-is-more" (in response to a patient request for an unnecessary and potentially harmful test); (2) SDM (in response to a patient choosing among multiple treatment options); and (3) disclosure of a medical error (in response to a patient having received inappropriate insulin dosing). The scenarios were informed by the medical literature and existing national resources, including the Choosing Wisely campaign of the American Board of Internal Medicine[30] (Natt N, Starr SR, Reed DA, Dyrbye LN, Park YS, Leep

Hunderfund AN, unpublished data, 2013-2014; 2014-2015).[31-33]

Longitudinal Curricular Threads

Longitudinal curricular threads are being developed to contextualize key SHCD competencies and provide opportunities for students to apply them in clinical settings. Three areas have been prioritized for thread development: HVCC care (to help reduce or eliminate the use of low-value care); SDM (to help reach mutually agreeable care plans that reflect patient values and priorities); and health-coaching skills (to help promote behavior change in a supportive, person-centered fashion). These threads equip students with prerequisite knowledge (years 1 and 2), provide them with graded skills practice (with peers, with patients, and/or via simulation as described earlier), and encourage them to use their skills during actual patient encounters. Student skills are more likely to progress from "knows how" and "shows" to "does" when teachers narrow the context in which skills are applied and provide appropriate support.[34] When this occurs, even early medical students can add value to patient care and the health care system.[35]

The SDM thread nicely illustrates this approach. Students are introduced to the concepts of EBM, SDM, and minimally disruptive medicine in year 1. In year 2, students receive a 1-hour lecture on principles of lung cancer screening during their oxygen-organ block, which includes references to the importance of SDM. In late year 2, students role-play in simulated SDM conversations by using a professionally developed decision aid for current or former smokers who are potentially eligible for lung cancer screening. During their year 3 internal medicine clerkship, students spend time with a team of nurses and nurse practitioners as they discuss lung cancer screening with actual patients. In that setting, students have the opportunity to lead the SDM conversation with patients and obtain feedback on their performance.

Although each of the "less-is-more," SDM, and health-coaching conversations has a slightly different focus, they all are intended to equip students with practical strategies to promote person-centered HVCC care in clinical settings. A session midway through year 3

gives students the opportunity to discuss challenges and strategies relating to synthesizing these skills in a busy practice, with seasoned clinical faculty leading these threads.

ASSESSMENT AND EVALUATION

All successful medical school curricula must include a thoughtful educational handover to residency (graduate medical education). A team of MCSM faculty comprehensively reviewed all Accreditation Council for Graduate Medical Education (ACGME) milestones from 25 specialties available online in September 2013. The team used an iterative, qualitative process to group the ACGME milestones into SHCD content domains, from which SHCD subcompetencies with corresponding milestones were derived. These subcompetencies were then mapped to the Association of American Medical Colleges Core Entrustable Professional Activities[36] and ACGME core competencies[37] (Havyer RD, Norby SM, Leep Hunderfund AN, Starr SR, Lang TR, Wolanskyj AP, Reed DA, unpublished data, 2013-2014). Faculty created milestone elements for the curriculum outcomes not represented among the ACGME milestones.[38] For example, new milestone elements were created to ensure that the leadership curriculum outcomes were adequately reflected. The resulting 15 SHCD subcompetencies and corresponding milestones were integrated into the end-of-rotation evaluations for the first 2 years of the curriculum.

Student Assessment: Years 1 and 2

The entire MCSM year 1 and year 2 curriculum is given with only a pass/fail option. Most SHCD assessments in the first 2 years are embedded within the online modules, the year 1 individual and group reflections, in-classroom group projects, and group presentations. Students at both campuses are required to take the new National Board of Medical Examiners HSS examination as a way of gaining experience with questions in the style of the US Medical Licensing Examination, covering some of the SHCD content. This experience allows students to compare their knowledge with that of students at other schools who are at a similar point in their training, and the results provide another means of curriculum evaluation.

Student Assessment: Years 3 and 4

For clerkship assessments, SHCD curriculum leaders are determining which SHCD learning outcomes map most clearly to the clinical clerkships and other clinical rotations so that they can assess a student's ability to transfer SHCD knowledge and skills from their preclinical years to clinical experiences. The most relevant SHCD milestones for year 3 clerkships will be included on end-of-rotation clinical evaluations.

Student assessments for the SHCD curricular activities between clinical rotations in year 3 and year 4 will be graded as pass/fail (similar to other MCSM content) and include successful completion of classroom projects (application of quality improvement methods, analysis of patient safety—related events, data analytics project), in addition to assessments in the remainder of the online modules. When feasible, a currently available published tool for assessing knowledge and skills will be used.

Curriculum Evaluation

Leaders in SHCD curriculum are using the Barr-Kirkpatrick hierarchy[39] as the key framework for evaluating the new curriculum. Reactions by learners (level 1 of the hierarchy) are obtained via the school's online system for generating student evaluations. An assistant dean for evaluation also meets with a focus group of students after each block to develop a summary of strengths and suggestions for improvement. Students who are participating members of the MCSM SHCD Curriculum Committee also provide feedback and suggestions for improvement. These 3 sources of information are collected and shared with domain team leaders and those facilitating face-to-face activities. Responses to a graduation questionnaire related to the SHCD curriculum will be tracked.

Modification of student attitudes and perceptions (level 2a) regarding cost-conscious care has been captured across the 4 years via a national cost-conscious care survey,[28] and a second survey has been designed to assess changing student attitudes regarding SHCD topics. Students' acquisition of knowledge and skills (level 2b) is evaluated via cohort results on the HSS examination of the National

Board of Medical Examiners, year 3 SHCD standardized patient scenarios, collated class performance on simulation activities, and successful completion of other year 3 assessments related to quality improvement, data analytics, and analysis of patient safety—related events. Students' behavioral change in real-world environments (level 3) is evaluated via cohort results of SHCD-related behaviors on clinical rotation evaluations and, if feasible, by instructors who complete a communication skills checklist for each student in year 4.

Although change in organizational practice (level 4a) and benefits to patients and staff (level 4b) are difficult to capture for any undergraduate medical education curriculum, goals include tracking the number of SHCD-related scholarly projects coauthored by MCSM students.

PARTNERSHIP WITH ASU AND MASTER OF SCIENCE DEGREE

Mayo Clinic and ASU created a partnership before beginning development of this SHCD curriculum. The curricular collaboration arose from mutual need: ASU needed a clinical context for its health care programs despite not having a medical center; MCSM needed some additional knowledge of health care delivery in certain content areas (eg, population health, health care economics, and leadership). The MCSM—ASU Certificate in Science of Health Care Delivery (earned by all MD diplomates who matriculate on or after 2015) is the fruition of this collaboration and reflects a student's achievement in successfully completing the SHCD curriculum. In addition, every student has the option to extend the certificate by completing an integrated ASU Master of Science degree in SHCD. Students who are accepted into this program transfer the 18 credits earned via the SHCD curriculum to ASU and complete the remaining 30 required credits via 3 online courses and a capstone research project. This project will also meet the MCSM research requirement.

CHALLENGES AND POTENTIAL SOLUTIONS

Student Perceptions and Satisfaction

Most student feedback (2 cohorts) on the year 1 curricular components has been positive. A minority of year 1 students in the second cohort perceived the first portions of the curriculum as having insufficient focus on areas seen by them as being at the *core* of medical school, a challenge shared by other developers of SHCD-related curricula.[40] Any school seeking to include substantial SHCD-related content may observe dissonance between SHCD content and some students' perceptions of what matters on US Medical Licensing Examination steps 1 and 2, as well as for the residency match. Multiple approaches are used to address this dissonance, including explaining the SHCD curriculum during medical school interviews, having residency leaders explain the importance of SHCD education, requiring all year 1 students to take the National Board of Medical Examiners HSS examination, having senior students teach some of the SHCD curriculum, and helping students explain the SHCD skills they bring during residency interviews.

Currently, no process is in place for measuring the variation across matriculating students with regard to depth of prior experience in one or more areas of SHCD. Although most students in the first 2 cohorts saw the importance and relevance of SHCD topics to their career in medicine, verbal and written feedback suggests substantial variation among matriculating students in prior experience and knowledge of major SHCD topics. Therefore, some students viewed the SHCD content for a given topic as too basic; others viewed it as new information. In recognition of this issue, faculty deliberately acknowledge this variation during the first week of year 1 and use it as an opportunity to model team learning in clinical medicine. Because students are likely to face challenges in applying some SHCD-related skills during their clinical clerkships, students meet with SHCD clinical faculty during dedicated time midway through year 3 to discuss the challenges they have experienced.

Faculty Development

Implementation of a curriculum with novel content and educational methods requires deliberate faculty development in both content expertise and delivery. Given that most SHCD faculty received little or no SHCD-related knowledge and acquired few, if any, such skills during their formal education, course directors chose SHCD faculty who are medical educators, have SHCD-related expertise, or

both. They also familiarized all SHCD faculty with the SHCD curricular framework and key concepts. The SHCD domain teams participate in 2 face-to-face retreats and several conference calls so they can update their colleagues on domain plans and progress, share challenges, and identify opportunities to improve the curriculum and the synthesis across domains for students. These discussions and the curriculum development process by SHCD domain teams have been crucial to success, especially because the first matriculating class of students begins at both the Scottsdale and Phoenix, Arizona, campuses of MCSM in July 2017.

Because the MCSM curriculum included minimal use of blended face-to-face and online learning before the SHCD curriculum was implemented, on-demand faculty development courses ("Creating Effective Blended Learning" and "Online Learning 101") were created jointly by MCSM and ASU to help faculty maximize their effectiveness. Many SHCD faculty and leaders also completed ASU's 2-week "Master Class for Teaching Online" course.

Faculty development in SHCD for everyone involved with student education is a considerable challenge and is ongoing on the basis of identified needs, gaps, and student feedback. For example, small-group learning and facilitation skills were identified as needs, and materials were developed and disseminated to the faculty for this topic. In addition, broader development for other MCSM faculty has included workshop sessions on the SHCD framework, with deeper discussions of each SHCD domain. Faculty members discuss ways in which SHCD could be integrated into the parts of the medical school curriculum for which they are responsible. Close collaboration among clerkship directors and clinical faculty (practicing physicians, residents, fellows, and other health professionals on clinical care teams) has begun so that faculty can learn to successfully role model the importance of SHCD knowledge and skills in practice.

Handover to Residency
Student Medical School Performance Evaluations (or Dean's letters) will summarize the SHCD curriculum and student achievement of SHCD milestones and let program directors know what they can expect from our graduates regarding our SHCD learning outcomes. Students will receive guidance about how to address SHCD-related questions during residency interviews so that program directors and other residency faculty can understand how graduates are expected to perform relative to residents who do not experience similar SHCD curricula during their undergraduate education.

Coordination and Management
Because MCSM is a national medical school and the 4-year curriculum will occur at both the Minnesota and Arizona campuses, the faculty and administrative staff have worked together from the beginning to ensure that what is designed will meet the Liaison Committee on Medical Education requirements for equivalence for curricular density, learning outcomes, and student assessments. The MCSM SHCD Curriculum Committee includes student representatives, Mayo Clinic faculty and administrative staff from Minnesota and Arizona, an ASU faculty leader, and an ASU instructional designer. To this end, detailed coordination and collaboration at each site and among ASU faculty have been required by each domain team. Project management and strong leadership support at many levels has been critical for keeping this complex matrix of people, curricular materials, timelines, and student satisfaction and outcomes appropriately balanced and optimized. Executive leadership issues are addressed by a separate group, with representation from MCSM and ASU.

CONCLUSION
Health care will continue to evolve and require skills not traditionally taught to ensure that health care professionals are successful. Although traditional knowledge in the basic and clinical sciences continues to be necessary, its potential impact will not be fully realized without SHCD education. An increasing number of schools (many in the American Medical Association's Accelerating Change in Medical Education consortium)[41,42] are developing or expanding curricula, with inclusion of topics that align with SHCD. A coordinated national effort to advance SHCD undergraduate medical education, including an increased emphasis on inclusion of SHCD-related topics on standardized examinations, is needed to address the remaining gaps and help all

schools identify and adopt best practices for SHCD-related curricula in undergraduate medical education.[43]

Through this innovative curriculum, MCSM students will start residency with a unique set of knowledge and skills focused on team-based, high-value, collaborative care that incorporates patient preferences and values and integrates and coordinates care for individual patients and populations of patients. These students, and others with exposure to SHCD-related curricula, are more likely to be prepared to see the health care system from multiple levels and have the leadership and systems-thinking skills necessary to enter residency and substantially contribute to improving both the rapidly changing system in which they will train and the care of patients.

Abbreviations and Acronyms: **ACGME** = Accreditation Council for Graduate Medical Education; **ASU** = Arizona State University; **EBM** = evidence-based medicine; **HSS** = health systems science; **HVCC** = high-value, cost-conscious; **MCSM** = Mayo Clinic School of Medicine; **SDM** = shared decision making; **SHCD** = science of health care delivery

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