Chapter

Curriculum Development: Foundations and Modern Advances in Graduate Medical Education

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Abstract

Curriculum development has undergone many transitions since the inception of medical education in the United States in the 1800's. In this chapter, we briefly review the history of curriculum development in medical education. We discuss the landmark models of curriculum development including the concept of a curriculum map and Harden's SPICES model of educational strategy, detail the six steps of Kern's foundational framework, and provide an overview of the PRISMS strategy. We address the importance of adult learning theory and the advancing understanding of education for the millennial generation, including implementation of the flipped classroom model of education. Finally, we turn our focus on contemporary applications of curriculum design, including the application of simulation to medical education, the rise of massive open online courses (MOOC), and the implementation of free open access medical education (FOAM) within undergraduate and graduate medical curricula.

Keywords: medical education, curriculum, pedagogy, andragogy, needs assessment, evaluation, objectives, adult learning theory, flipped classroom, technology-based learning, simulation, massive open online courses (MOOC), free open access medical education (FOAM, FOAMed)

1. Introduction

It can be argued that the naissance of traditionally-regarded medical education in the United States began in the civil war era with for-profit "proprietary schools" which were typically less than one year in duration and the contents of which were delivered only in didactic form [1]. The Flexner report [2] in the 1920's ushered in a new era where an emphasis on lectures and textbooks in medical schools were set aside for laboratory and clinical teaching. Medical education moved from a substantive system reliant on memorization to one which was now procedural - a focus on the process itself of acquiring scientifically sound information. Between the two world wars, undergraduate medical education was further shaped into the recognizable modern form with the first two years containing preclinical education, and the second two years with clinical rotations in the major specialties. Additionally, the concept of post-medical school training took hold with the development of internships

and residency programs. Although a multitude of medical schools flourished within university systems, curricula were implemented with variable levels of success [1]. In the latter half of the 20th century, there remained an ongoing search for the ideal curriculum - as well as the methods themselves for curricular development.

A curriculum is defined as a sophisticated blend of educational strategies, course content, learning outcomes, educational experiences, assessment, the educational environment, and the individual students' learning style [3]. A process known as curriculum mapping has been described by Harden as a method to organize curricular contents. Curriculum mapping can help both educators and learners by displaying the key elements of a curriculum, and the relationships between them. Learners can identify what, when, where, how, and why they will learn, while educators can visualize their role within the entire curriculum. The scope and sequence of learning is made explicit, links with assessment are clarified, and curriculum planning becomes more effective and efficient. In this way the curriculum is more transparent to all of the stakeholders including the educators, the learners, the curriculum developer, and all other important stakeholders. The windows through which the curriculum map can be explored may include: (1) the expected learning outcomes; (2) curriculum content or areas of expertise covered; (3) assessment; (4) learning opportunities; (5) learning location; (6) learning resources; (7) timetable; (8) educators; (9) curriculum management; (10) learners. The key to a really effective, integrated curriculum is to get educators to exchange information about what is being taught and to coordinate this so that it reflects the overall goal. This can be achieved through curriculum mapping, which has become an essential tool for the implementation and development of a curriculum. Faced with curricula which are becoming more centralized and less departmentally based, and with curricula including both core and optional elements, the teacher may find that the curriculum map is the glue which holds the curriculum together [4].

All teaching activities, whether great or small can represent a curriculum. Beginning in the 1980's, Harden et al. [3] proposed a model for educational strategies in curriculum planning with the mnemonic SPICES:

S Student-centered, with students assuming responsibility for their own learning. This requires the student to decide their own learning objectives, decide the sequence and pace of learning, and assess their own progress, all under the guidance of a teacher.

P Problem-based, with application of knowledge to and derivation of knowledge from problems in clinical practice, health delivery, medical science and research.

I Integrated teaching, unifying subjects across academic subjects or departments such as anatomy, pathology, biochemistry, and clinical medicine.

C Community-oriented, with a goal of preparing students to ultimately work and serve in areas of health care need within the community

E Elective study periods, which incorporate some flexibility within the curriculum and give students the freedom to choose subjects and projects.

S Systematic approaches, moving away from the apprenticeship model and emphasizing learning that is not "left to chance" but rather planned and recorded.

In 1998, David Kern composed a seminal work in the field of modern medical education, espousing a six-step approach to the formation and implementation of new curricula [5]. Since the initial publication of Kern's text, the means by which medical education are delivered have remained in as much flux as the state of American healthcare itself. With the implementation of the Affordable Care Act and its emphasis on improved access and quality of healthcare, new competency-based frameworks have been the scaffolding on which a multitude of new approaches to medical education have developed [6, 7].

2. Kern's framework for curriculum development

Kern's foundational Framework for Curriculum Development [5] is comprised of six steps. While these steps are discussed in sequence below, it is important to keep in mind that the steps may occur in parallel as well as out of sequence; in fact, the various steps are intertwined and dependent on one another **Figures 1–3**.

1. *Problem Identification and General Needs Assessment*: Kern prompts educators to consider what prompts an educator to start work on a curriculum? Is the goal to impart new knowledge or a new technique? Or rather is it a reflection of demands from an accreditation agency or hospital administration? An important consideration when met with the idea (or demand) for a new curriculum is whether the resources required for design and implementation of a new curriculum is worth the time and effort involved - will it ultimately serve to improve a healthcare provider's knowledge base and therefore a health outcome? The essential component of this step is performing a *general needs assessment*, or *problem identification*. This is the gap between a current and desired approach to knowledge acquisition or how a health problem is addressed. There are many potential means to making these determinations including expert opinion, group consensus, or previously disseminated evidence. This step is important to justify later dissemination of the newly designed curriculum because it supports broader generalizability.

2. *Targeted Needs Assessment*: This is the step where the general needs assessment in Step 1 is applied to the actual learning environment and learners. Because a *targeted needs assessment* is the step where an ideal approach is superimposed upon the subject of interest, involvement of stakeholders (including teachers, learners, and administrators) is critical to appropriate framing of the problem. Herein is where one collects baseline information on the learners of interest. What are their knowledge base and known deficiencies? What motivates these learners? What are their preferred learning

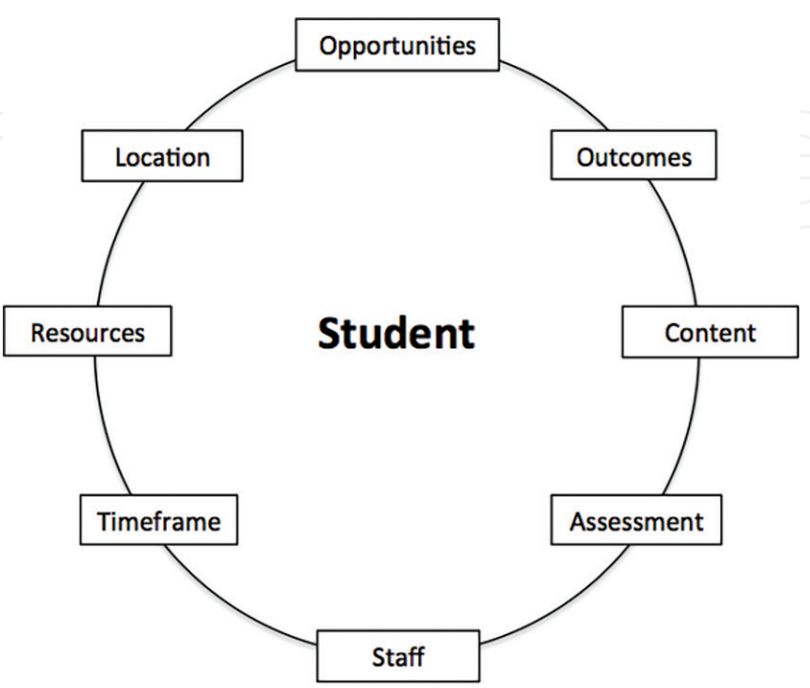

Figure 1.
Curriculum map (adapted from Harden [4]).

styles? There are a multitude of assessment methods that can be employed (including informal discussion, interviews and focus groups, direct observation and exams). Ideally, when collecting this information, markers of accuracy and validity are included.

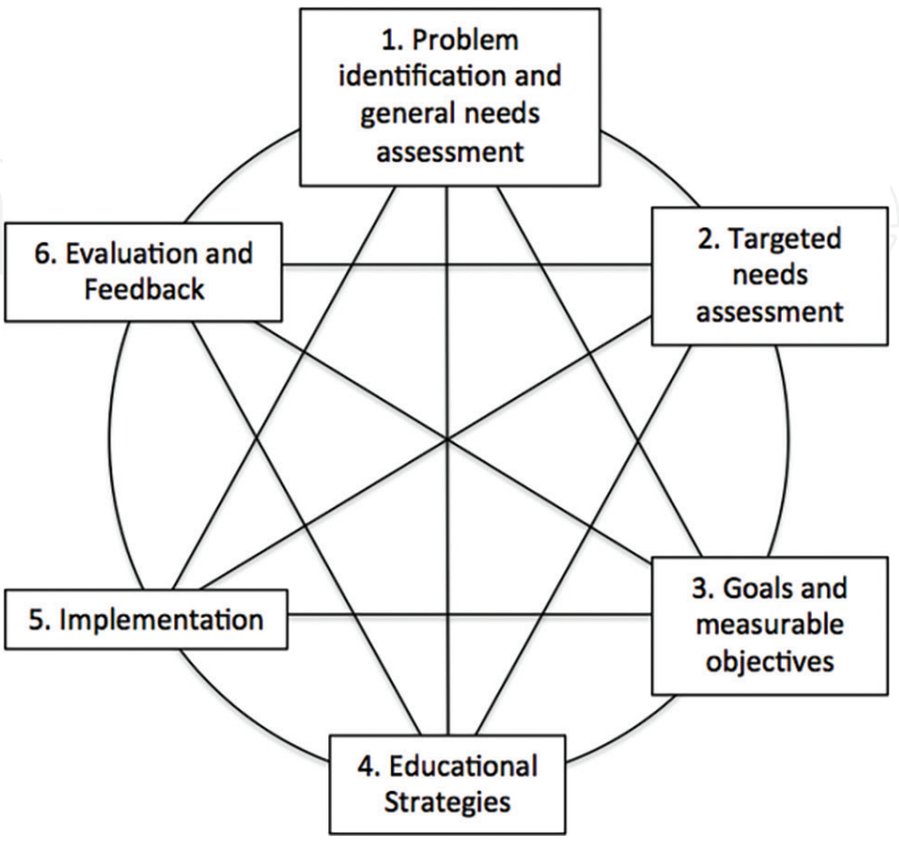

Figure 2.
Kern's curriculum development model (adapted from Kern [5]).

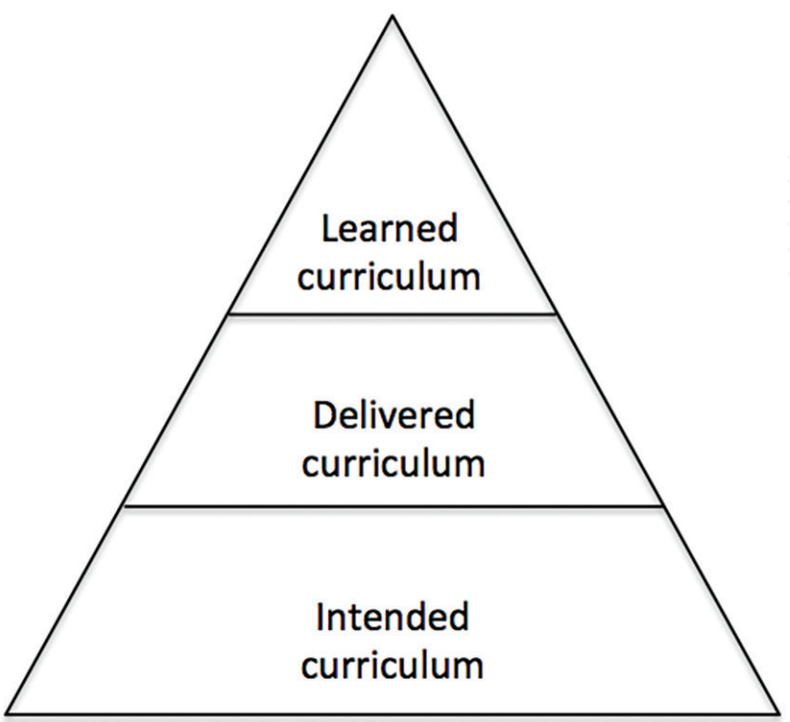

Figure 3.
Curriculum levels (adapted from Prideaux and Harden [4, 10]).

3. *Goals and Objectives*: The development of strong curricular goals and objectives is vital to curriculum development. They define the expectations of the curriculum and guide the remainder of the developmental process. In considering this step, *goals* are defined as broad desires to accomplish while *objectives* are specific and measurable. An objective is the targeted result of a curriculum implementation and must be outlined prior to implementation to have a targeted result. Importantly, a goal must be well-written in order to be useful, and should follow this template: (who /will do/how much/of what/by when). Objectives can target the learners themselves, the educational process, or specific systems-level outcomes. Objectives should be developed using the SMART framework. This framework guides the educator in the development of objectives that are Specific, Measurable, Achievable, Realistic, and Time-based. Bloom's Taxonomy, the preeminent model for objective development, focuses on the use of action verbs describing the cognitive process by which learners work with knowledge. This approach is designed as a hierarchy where higher-level learning occurs as objectives are developed that are higher on the defined framework. Bloom's Taxonomy is often described as a pyramid, where the lowest level of learning objectives is at the bottom. In ascending order, these learning, action verbs include: remember, understand, apply, analyze, evaluate, and create [8]. When developing objectives, be sure to exercise caution. An overly exhaustive list of goals and objectives can overwhelm both educators and learners, limit creativity, and limit learner-centered education.

4. *Educational Strategies*: The job of a curriculum developer is to facilitate learning; however, there are a multitude of means by which this facilitation can occur. In the latter part of the 20th and in the 21st century, the process by which learners learn is increasingly better understood. The content of a curriculum naturally flows from learning objectives once they are established. Kern espouses using a variety of different strategies for reinforcement of a particular topic with the rationale that this will not only increase the degree of learner interest but also increase learner investment since they will inevitably realize their ideal learning methods reflected in the curriculum. Multiple educational methods should be used and chosen based on feasibility and available resources. For example, a simulation session should not be developed if the educators lack the necessary equipment. Similarly, educators should implement methods that are literature based, best methods for adult learners. Recently, self-directed learning has been increasingly recognized as an important aspect of medical education curricula due to its importance in continuing medical education. As a learning method, it should be incorporated into developed curricula due to the importance of the skill in lifelong learning. Not all learners are adept at this learning style; therefore, learners must be fostered with specific strategies for maximizing their self-directed learning practices.

5. *Implementation*: After the time, effort, and resources expended in the first four steps outlined above, the curriculum is finally ready for implementation. In order to successfully implement a curriculum, four stages will ideally occur: a) generating support from stakeholders including learners, instructors, and relevant administrators; b) plan for implementation of desired change including identification of resources such as personnel, time, facilities, and funding; c) operationalize the intervention, ideally planning for a pilot period, phase-in period, and full implementation of the curriculum; and d) ensure viability and longevity of the curriculum by involving multiple parties so the curriculum does not depend on the efforts of a single individual.

6. *Evaluation and Feedback*: Ultimately, the contributions and accomplishments of the new curriculum should be recorded in a system of evaluation. Increased knowledge or ability can be marked by assessments on the level of the individual. Taken in aggregate, individual assessments can be used for evaluation of the program of instruction. What the evaluation encompasses is driven by the purpose of the evaluation itself - is it to judge the success of the program itself, and by what marker? Is it to justify the allocation of resources to further the mission of the curriculum? Is it to document the achievements of the individual who designed and implemented the curriculum? A successful curriculum is continually developing. In response to evaluative and feedback data, effective curricula remain dynamic and adjust based on the evolving needs of the learners. Finally, evaluations of a program once performed should be published for broader dissemination.

While Kern's framework is classically described as a six-step approach, an argument can be made regarding the inclusion of a seventh step, which involves dissemination of educational materials and outcomes. While Kern mentions this in his sixth step, its importance bears a separate step. The dissemination of educational materials has innumerable advantages. By disseminating educational materials, educators can increase collaboration, while receiving external feedback and peer review of educational materials. This ensures continued improvement of the educational product delivered. Similarly, physician educators lack time to complete all of the educational innovations they desire, By sharing educational materials, educators can minimize redundant work, especially since other educators are delivering similar content. Finally, by disseminating their educational materials and curricular outcomes, curriculum developers and educators can achieve recognition and academic advancement for their efforts.

3. An evolving perspective on curriculum design

The PRISMS model, proposed by Bligh [9] propagated new strategies for curriculum development including increased use of technology and problem-based learning, and emphasized the need for more clinical experience in medical school and more protected time for learning during residency. The PRISMS model can be broken down into each of its components.

- P: Product-focused, as the curriculum should emphasize applications to clinical practice and be practice-based. This includes acquisition of professional behaviors, application of knowledge to the real world, and feedback from patients.

- R: Relevance to communities and students, meaning that curricula should be planned around outcomes with a focus on local needs, and revised and reviewed frequently.

- I: Interprofessional, in that a culture of multiprofessional and interdisciplinary learning should be promoted, with emphasis of teamwork and collaboration between all persons involved in the care of the patient (eg. nursing, physical therapy, occupational therapy) with respect to clinical care, but also to education and research.

- S: Smaller class sizes and shorter courses, with units as building blocks implementing modern technology.

- M: Multisite, further emphasizing the product-focused goal of the curricula allowing learners to ultimately care for patients in diverse settings including urban, rural, community sites, and academic teaching hospitals.

- S: Symbiotic, in that each of the above components combine to form a cohesive and coherent philosophy and product.

The guiding philosophy of the PRISMS model includes respect for autonomy of the adult learner while emphasizing group learning and reflection. Further, content must be context-based, relevant, and meaningful.

In 2003, Prideaux published an additional means to conceptualizing curriculum design [10]. In this work, a broader framework for curriculum design is described in which curricula fall under one of two models: prescriptive models, in which curriculum designers adhere to a stepwise guidebook to create curricula, and descriptive models, which describe what curriculum designers have accomplished once a curriculum has been implemented. The overarching goal for either design is that curriculum designers are agile in adapting to current environment, not continuing to teach that which is outdated. Additionally, curricula should develop in context of the community it was designed to serve in order to enhance health service provision.

Prideaux outlines the three sequential "levels" of a curriculum: 1) the planned curriculum, or what is intended 2) the delivered curriculum, or what is taught, and 3) the experienced curriculum, or what is actually learned by the intended audience. In this learner-centered concept, four main elements of a curriculum are identified: the content, strategies for teaching and learning, assessment of individuals, and evaluation of the program. Curriculum design is therefore organizing these four elements into a logical pattern of implementation. To communicate the implementation process to all parties, Prideaux promotes the use of a curriculum map [4], of which different versions can be created from the point of view of students, teachers, administrators, and accrediting authorities.

3.1 Adult learning theory

Facile adult educators continue to recognize that adults cannot be taught using traditional pedagogical approaches; in fact, adults are always voluntary learners that can disappear from learning experiences that do not satisfy or engage them. The practice of educating adults has been deviating from traditional pedagogical approaches for some time; therefore, the technology of andragogy was developed. Andragogy refers to the science of adult education. Important conditions of learning and associated principles of teaching developed by Malcolm Knowles that define andragogy are illustrated in **Table 1**.

Curricula and associated educational materials should be developed using literature-based best practices in adult learning theory. Andragogy, the science of adult learning, differs substantially from traditional pedagogical approaches. Adult learning is most clearly described using seven core principles. Adult learning builds from established learning needs, is practical and problem-centered, necessitates a positive learning climate, occurs when new ideas are integrated with existing knowledge, promoted when respected by both educators and other learners, is self-directed, and builds on previous experience [11]. Ultimately, curricula should employ educational materials that create a climate of assisting learners to acquire information and incorporating their experiences to master the content through session structure. Finally, curricula should help learners test their ideas, retain new information, and apply that information clinically [11]. Adult learning is most successful when learning is active and problem-centered, learners take ownership of the classroom and are accountable for demonstrating mastery, and feel safe, respected and successful [12].

Conditions of learning	Principles of teaching
The learners feel a need to learn. The learning environment is characterized by physical comfort, mutual trust and respect, mutual helpfulness, freedom of expression, and acceptance of differences. The learners perceive the goals of a learning experience to their goals. The learners accept a share of the responsibility for planning and operating a learning experience, thus resulting in a commitment toward it. The learners participate actively in the learning process. The learning process expands on the experience of the learners. The learners have a sense of progress toward their goals.	(1) The teacher exposes students to new possibilities for self-fulfillment. (2) The teacher helps each student clarify aspirations for improvement. (3) The teacher helps learners diagnose the gap between aspiration and current level of performance. (4) The teacher provides comfortable physical conditions conducive to learning. (5) The teacher respects each student's feelings and ideas. (6) The teacher seeks to build relationships of mutual trust and refraining from judgment. (7) The teacher exposes their own feelings and contributes as a learner. (8) The teacher involves students in the process of developing learning objectives. (9) The teacher provides insight regarding available educational resources and methods in which to learn collectively. (10) The teacher maintains organization among the learners in order to share responsibility in the process of mutual inquiry. (11) The teacher helps to exploit learner experiences through discussion. (12) The teacher designs a session based on the level of experience of the learners. (13) The teacher helps students apply new learning to their previous experiences in an effort to make learning meaningful and integrated. (14) The teacher involves students in developing mutually acceptable criteria and methods for measuring progress toward learning objectives. (15) The teacher helps students identify and apply procedures for self-assessment.

Table 1.
Andragogical conditions of learning and principles of teaching (adapted from Knowles [11]).

3.2 Flipped classroom pedagogy

Medical education continues to evolve by shifting from traditional, lecture based teaching to other educational approaches that promote higher-order learning and active learner participation [13]. The flipped classroom method, one particular learning model, has become increasingly popular in medical education. In this educational pedagogy, learning materials are consumed independently in a learner-paced manner at home, while classroom time is devoted to knowledge application, case-based learning, or active discussion and problem solving. Conversely, within a traditional classroom, foundational knowledge is often passively transferred to learners through lectures delivered by instructors. Following the teaching session, learners actively use and apply the knowledge outside of the educational setting [14, 15].

Influenced by the preference of millennial learners for immediate, digital educational materials, medical educators are constantly searching for the most efficient and effective approach [16]. Active, self-directed learning, a necessary component of this learning model, is a vital skill that provides the foundation for adult learning and continuing education [15]. Additionally, this model is also supported by the educational theory of social constructivism [17, 18]. Group collaboration encourages modeling, scaffolding, and feedback that engage learner preconceptions and build upon existing understanding [19]. This model promotes a higher level of learning, defined by Bloom as analysis, synthesis, and evaluation [8, 19, 20]. As a result, increasing numbers of educators have adopted the flipped classroom strategy in both medical and more traditional educational settings [21–28].

4. Contemporary applications of curriculum design

4.1 Simulation in medical education

One unique application of curriculum design is in the field of simulation in healthcare. Simulation has long been used in fields outside of medicine including aviation and commercial airlines, aerospace, and the military. Simulation in healthcare goes as far back as the 18th century when models of the pelvis were used by midwives for newborn delivery instruction. In the modern era, simulation in healthcare, initially pioneered by anesthesia, is now broadly adopted by many specialties including emergency medicine, critical care, trauma, obstetrics, pediatrics, and radiology [20]. Simulation is employed as early as the pre-clinical years in medical school, where applications include clinical skills, clinical medicine, physical diagnosis, anatomy and physiology. In the second half of medical school during clinical clerkships, the specialties which most commonly employ simulation are internal medicine, pediatrics, and emergency medicine. In residency, nearly 90% of programs report some use of simulation, most frequently in the fields of internal medicine, emergency medicine, general surgery, pediatrics, anesthesia, and obstetrics and gynecology [30]. This broad use of simulation has been ushered in by the modern era of healthcare delivery in which there is an expectation that practitioners are prepared to care for patients prior to encountering a pathology or procedure, with less reliance on serendipity to acquire the wide range of skills necessary for clinical practice but instead methodically structuring a curriculum within an outcomes-based framework with assessments and monitoring at regular intervals [31].

Simulation is broadly defined as "advanced technologies recreating the clinical experience" [31], with the goal to train healthcare practitioners to safely conduct patient care. More specifically, it is the imitation of the operation of a real-world process or system over time, with the ability to show real effects of conditions and actions, or when a real system cannot be engaged because it is either not accessible, dangerous, or does not exist [29]. Simulation encompasses cognitive and affective domains and encompasses a wide range of techniques and approaches.

The types of simulation can be framed by the degree of fidelity and the means by which the simulation curriculum is delivered. The degree of fidelity, or extent to which the system mimics real life, in simulation can be gauged by how similar the simulation model is to real life with respect to equipment, environment, and physiological parameters [31]. There are many vehicles for delivery of simulation-based learning, including partial task trainers (ie a model arm for venipuncture), computer-based models, virtual reality and haptic systems (with kinaesthetic and tactile sensation such as for robotic surgery), integrated simulators which employ manikins and computer-controlled outputs such as vital signs, simulated or standardized patients, and simulated environments such as for disaster training.

Steps in the curriculum design in simulation include acquisition of valid source information, use of simplifying approximations and assumptions, and evaluation of the fidelity and validity of simulation outcomes [32].

McGaghie [33] lists features and best practices within simulation curriculum design and implementation, which include:

1. feedback

2. deliberate practice

3. curriculum integration

4. outcome measurement
5. simulation fidelity
6. skill acquisition and maintenance
7. mastery learning
8. transfer to practice
9. team training
10. high stakes testing
11. instructor training
12. educational and professional context

These features and best practices can be applied to the principles of curriculum development laid out in Kern's work, such as in developing a simulation-based mastery learning curriculum [34].

4.2 Massive open online courses

Although Kern's framework for curriculum development remains foundational to medical education, new approaches and applications to this framework continue to shape its application in the 21st century. One novel approach in the context of collaborative online learning models such as Massive Open Online Courses (MOOC), which are hailed as a paradigm for graduate medical education [13]. A course meets the definition of a MOOC when a single course has thousands enrolled (massive), and can share information through meaningful and free (open) online learning environments (online courses) [35, 36]. MOOC were originally based on curricula models in higher education but are distinct from campus courses in that they typically have discussion fora where recommended readings and short videos are discussed in online fora by diverse learners [36]. Further, assessments are all carried out online. The benefit of MOOC are that they can involve learners with a more diverse range of backgrounds, enriching courses beyond education that can be delivered by the host institution alone [37]. Based on the concept of MOOC, online courses have proliferated. MOOC have the ability to expand on known means of computer-based learning in medical education.

A publication by Goldberg and colleagues [35] addresses the availability of MOOC on medical topics. They are advocates for MOOC as an innovative medical education tool for many reasons. With the foundational philosophy that quality health care needs to be effective, high-quality, equitable, patient and family-centered, and delivered by an interprofessional team comprised of educators from all professional programs, the MOOC may have a unique advantage in medical education. MOOC have the inherent potential of educating consumers, students, and healthcare providers alike; the MOOC format has no constraints of time, geography, or level of education, and offers the advantage of being asynchronous. From a big picture standpoint, it has the potential to strengthen communication and foster collaboration nationally and internationally while increasing public health literacy for patients, model innovation for learners, and offer continuing medical education for providers. Although detractors may assert that MOOCs will undermine

traditional methods of education, a more cohesive view would espouse that while MOOC cannot fully supplant existing curricula, they can be complementary and augment existing forms of medical education. Goldberg et al. reviewed existing offerings for MOOC on medical topics, finding that the majority of topics address education for chronic care conditions, health literacy for the general public, and evidence-based medicine for healthcare providers. Further research ranking the relevance of MOOC to post-graduate training reveals that many courses are relevant and applicable, course duration and workloads appropriate for physicians [38].

As the role of MOOC in medical education is emerging and evolving, further literature has since been published which offers a prescriptive view of how to implement a MOOC [37]. Additional acknowledged roles for MOOC in medical education include integration within campus courses, increasing interprofessional collaboration, enabling the flipped classroom, and for continuing medical education. Within these areas, Pickering and colleagues introduce a framework for developing, delivering, and evaluating a MOOC, with the following stepwise advice:

1. Enroll in a MOOC to experience the format first-hand

2. Learn from other MOOC enthusiasts to understand practical implementation and time commitment; network for multi-institution MOOC or between departments

3. Develop a MOOC topic that you are passionate about, accounting for intended audience and MOOC length; perform a preliminary search of what is available within this topic. Pitch to intended audience to gauge enthusiasm.

4. Recruit a committed and enthusiastic team to support the MOOC's development and delivery, including a lead academician to develop the curriculum, write lecture scripts, create learning objectives, and set assessment questions. Recruit colleagues to review the curriculum, and create faculty development programs addressing how to support learners on a MOOC.

5. Develop a curriculum map to guide content development, keeping in mind the target audience, academic level of content, and duration of the course. The map should be accessible to learners to serve as a scaffold on which they can track their own progress.

6. Create a clear project plan to deliver the MOOC. The authors estimate that it takes approximately one year to create the content for a single course.

7. Create video content based on good educational practice - short, with a conversational style, and tailored to the course.

8. Construct an assessment profile, keeping in mind scalability to thousands of learners who require timely and accurate feedback. The format which lends itself best to these requirements is multiple choice quizzes, but other options include peer assessments.

9. Promote your course with a clear message, aspiring to both a local and global audience.

10. Provide a supportive learning environment with which your learners can interact, including guidance to the learner on how to use the MOOC.

11. Devise a strategy to evaluate the course after implementation, which may include course enrollment and completion data, pre- and post-test results, and targeted questionnaires for a subset of learners.

12. Share the experience of creating a MOOC through discussion and publication to aid colleagues with a similar interest.

4.3 Free open access medical education

Free Open Access Medical Education (FOAM or FOAMed) is defined as "a collection of interactive online medical education resources" including blogs, podcasts, tweets, videos, and other web-based media. It is "educational social media for medicine" with open sharing and collaboration with attribution and recognition of the work of others [39]. The object of FOAM is to form an online community to share ideas and accelerate translation of research into clinical practice [40].

FOAM is a sphere of medical education which has expanded rapidly in recent years, led by the specialties of Emergency Medicine and Critical Care [40]. In one study examining expansion of FOAM, in the time period from 2002 to 2013 the number of FOAM resources available grew from two blogs and one podcast to 141 blogs and 42 podcasts [41]. By the most recent estimate this number has expanded to 240 [39]. While the United States, Australia, and the United Kingdom lead in countries who predominantly consume FOAM, the potential for dissemination of medical knowledge via FOAM in lower resource countries has also been studied [40]. Outside of Emergency Medicine and Critical Care, the use of FOAM has been detailed in Emergency Medical Services [42, 43] and Pediatrics [44].

Since the inception of FOAM, some guidelines have been published from expert users on the optimal means to using FOAM and how to evaluate the quality of resources. Weingart has established a beginner's guide to FOAM with a stepwise hierarchy in which learners can progress from novice to expert: existence (create online profile), safety (learn the rules of engagement to avoid problems), consumption (learn to effectively use resources), collaboration (engage with others), creation (of content) [45]. In another approach, a collection of four strategies to evaluate and engage in FOAM are 1. cultivate digital mentors 2. browse the most popular FOAM websites 3. use critical appraisal tools for FOAM and 4. contribute new online content.

A multitude of applications of FOAM have been promoted, including integration into existing graduate medical education curricula. General guidelines and suggestions for use have been proposed, including promotion of approved FOAM websites by a residency program to residents, creation of a residency Twitter account to interact with users, involving residents and faculty in creating and sharing FOAM, and application in flipped classroom and asynchronous curriculum models [46, 47]. In one training program, application of FOAM in the curricula has been accomplished via a model of team-based learning using the Academic Life in Emergency Medicine (ALiEM) Approved Instructional Resources (AIR) series, allowing faculty oversight and discussion of clinical applications [48]. The format of FOAM naturally adapts to the asynchronous component of residency education and courses such as "Asynchrony" incorporate an assignment, discussion, and quiz into the curriculum [49]. Additional attention has been paid to the use of podcasts in medical education. In comparing media, learners have been shown to improve their knowledge base equally with blogs and podcasts [50].

Remarkably, in a survey of trainees in Emergency Medicine, the podcast was found to the most popular means of obtaining medical knowledge, with reported

use by 35% of residents surveyed compared to 33.6% of residents who report predominantly reading textbooks. Podcasts were additionally endorsed as the most beneficial means of learning [51]. The use of podcasts by learners has also been detailed in undergraduate medical education in a study examining usage conditions (most popular during driving, chores, and exercising) and knowledge retention (increased compared to the existing undergraduate curriculum alone) [52].

In addition to podcasts, Twitter has emerged as another medium for exchange of information in medical education [47]. The concept of an online community of practice exists wherein an open digital space and non-hierarchical structure promote information sharing, and knowledge translation. Further, social media-based platforms such as Twitter allow for the development of a strong group identity among educators and learners who partake.

The importance of critical appraisal and vetting educational content of FOAM cannot be emphasized enough. Due to the nature of FOAM, in which anyone can be a consumer or producer of online content, not all resources are of equal quality. Many FOAM articles and resources can be opinion-based and not all equally grounded in evidence-based medicine. Further, it can be hard for the user to discern whether content draws predominantly from the former or the latter. Multiple index markers have been developed to determine the quality of resources from which a learner is gaining information. These include adherence to the Health On the Net code of conduct, and application of the DISCERN score, which were developed to appraise online resources for patient use. With respect to medical education for practitioners, metrics to determine the quality of online resources such as the Quality Checklists for Blogs and Podcasts, ALiEM AIR score, and METRIQ score [53] have been newly developed and applied.

Despite the propagation and application of these quality markers, detractors of FOAM do list downsides of the format including little editorial oversight of material, overly rapid translation of information to patient care, and the outsize influence of figures with an eminent online presence [54]. When queried, the FOAM resources recommended by trainees and attending physicians varies widely and is also not a reliable indicator of quality [55].

With respect to representation of core content for learners in FOAM, in one study of core content for Emergency Medicine trainees, FOAM related to airway management, interpretation of EKGs, propagation of new research and evidence-based medicine, resuscitation, and point-of-care ultrasound were overly represented compared to the least represented topics of cutaneous disorders, hematologic disorders, atraumatic musculoskeletal disorders, and obstetrics and gynecology [56]. Despite FOAM's popularity in recent years, FOAM alone is not sufficient for trainees to learn all areas relevant to practice in a specialty.

With respect to FOAM and MOOC as they pertain to curriculum developers, a novel approach to curriculum development implemented by Shappell et al. [57] involves crowdsourcing each step of curriculum development as it pertains to the Emergency Medicine residency curriculum. In Shappell et al.'s scoping review, an expert panel of authors searched for key terms within each step of curriculum development with inclusion of references to FOAMed. In determining the extent to which each of Kern's six steps are referenced in FOAMed, they were able to gain an understanding that the steps of curriculum development which are underrepresented, which include (1) articulating goals and objectives and (2) tools for curricular evaluation. Ultimately, it is the authors' goal and assertion that crowdsourcing curriculum development will diffuse the burden of creating a comprehensive online learning center and will help developers consider how their contributions will align with the work of others.

One example of a successfully-implemented FOAMed curriculum is the Foundations of Emergency Medicine curriculum for emergency medicine

residents [58]. Initially developed for emergency medicine interns at Northwestern University in 2014, the Foundations curriculum uses a flipped-classroom model to provide a longitudinal year-long course for understanding cardinal presentations and management strategies for "cannot miss" diagnoses. Since its inception at a single institution, the Foundations curriculum has rapidly expanded across more than a hundred institutions to encompass all levels of resident learners, accomplished through crowdsourcing from educational leaders across the field. Much of its expansion and success can be attributed to its FOAMed format, as the curriculum is readily accessible to all residency leadership in emergency medicine.

5. Conclusion

The concept of curriculum development has come a long way since the inception of medical training in the United States and the formalization of medical education. As the Flexner Report ushered in a new era shifting focus from reliance on lectures and textbooks to the real-life application of medical knowledge, medical education was further shaped by the implementation of post-graduate training. In parallel, the concept of curriculum development for educators of both medical students and resident trainees took hold. Strategies for educators such as Harden's curriculum mapping and Kern's landmark six-step approach for curriculum design proved seminal to the field, while new understanding in adult learning theory shaped the means by which information was propagated. In the contemporary era, new advances in technology have allowed for radical models for medical education to spring forth, including the use of simulation, massive open online courses, and free open access medical education. Based on the advances of the past few decades, the future of curriculum design in medical education is hard to predict but is sure to hold even more innovation.

Conflict of interest

The authors declare no conflicts of interest.

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