SAFETY BY DESIGN

Issues in the design of training for quality and safety

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The US healthcare delivery system is in a state of change. Medical science and technology are advancing at an unprecedented rate, while cost containment and productivity pressures on clinicians make the clinical environment less than ideal for training. Training is one of the vehicles for addressing new knowledge requirements and for enhancing human and system based performance. Yet the theoretical underpinnings and design aspects of training have been largely unrecognized and unexamined in health care. This paper first explores changes in the practice of medicine and the healthcare delivery environment. It then describes how healthcare training and education can benefit from findings in the behavioral and cognitive sciences. It describes the systems approach to training and explores the extent to which a systems approach can be applied to the clinical environment. Finally, the paper examines innovative training and education techniques that are already gaining acceptance in health care.

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As healthcare providers experience rapid scientific and technological change, training is frequently recommended as a way of keeping up with the change. Understanding the nature of the change is a crucial first step, after which efforts typically turn to identifying ways of achieving desired training outcomes. In the present paper we examine whether there is anything in the psychology of learning and cognitive science literature to help guide the deployment of appropriate training methods. At the same time, it is not unreasonable to ask what other professions do—especially those that invest heavily in training such as the military—with respect to the design and development of training. Is there an orderly design process or systematic approach that is followed for the design, development, and evaluation of training materials and programs? If so, can these approaches be applied to clinical environments? What are the advantages and limitations of doing so? While practitioners in medicine and health care are not known to be among the early adopters who embrace and take advantage of educational innovations and new instructional technologies, it would be a mistake to assume that medical education is stagnant and not moving forward. How are medicine and health care taking advantage of new ways of thinking with respect to curriculum reform and the acquisition of clinical skills?

With its heavy reliance on immersing students and residents in the clinical environment where learning occurs adventitiously, the design aspects of training receive very little attention. In fact, that there is an underlying design process to training may come as a surprise to healthcare professionals. To gain a better understanding of factors that influence the design of training, this paper addresses five issues stated in the form of questions (box 1).

HOW IS THE PRACTICE OF MEDICINE CHANGING?

The scientific foundation of medical practice has expanded significantly in the past 20 years. Advances in genomics, proteomics, neuroscience, immunology, and the epidemiology of disease represent unparalleled challenges for those involved in medical education and training.[1] Not only will medical education and training need to draw from a vast accumulation of existing approaches that have proved successful in the treatment of disease but, to keep up with the expectations of the 21st century, physicians and other members of the care team will also need to master the application of new drug armamentariums, new imaging technologies, and minimally invasive surgical techniques if some of our more intractable diseases are to be effectively and humanely addressed.

At the same time, clinical practice in the US is changing as a result of a wide range of economic and societal factors. With the prevalence of managed care, solo physician practices are decreasing in number.[2] Larger organizations and practices, better equipped for dealing with third party payers and for leveraging costs associated with new medical technologies and information systems, are attracting greater numbers of physicians starting their careers. Nursing, however, continues to experience shortages. Individuals who in earlier days might seriously have considered nursing are now finding ample opportunities in other sectors of the economy where promotions, normal hours, and respect of colleagues are easier to come by. The location of medical practice has been steadily shifting from inpatient to outpatient settings where less invasive procedures no longer require prolonged hospital stays. Given the economic incentives to move patients out of hospitals as soon as possible, there has been a concurrent migration of sophisticated medical devices into the home. Home care device use becomes an issue, especially with patients who are aged and where adequate assessment of the capability of home caregivers (also likely to be aged) and the suitability of the home environment for such use is lacking.

Box 1 Basic issues relevant to the design of training

- How is the practice of medicine changing?
- Do education and training benefit from a scientific and theoretical foundation?
- What is the systems approach to training?
- Can a systems approach to training be applied to clinical environments?
- Is medicine taking advantage of new educational and training innovations?

Until very recently, healthcare delivery has been relatively untouched by advances in information technology and system engineering approaches that have transformed other sectors of society.[3 4] Efforts in the UK and US are underway to change this. In the UK, for example, the National Health Service Connecting for Health (CFH) program shows considerable promise as a high capacity network and national data spine for making available medical information such as test results, radiographs, and scans on individual patients wherever and whenever needed on a confidential basis. Receiving less attention, however, is the training requirement that new technology infrastructures may impose on physicians and other providers who may be somewhat sceptical of the need for change in the first place.

Demographics are also shifting. With the baby boomer generation on the threshold of retirement, new challenges in terms of treating chronic ailments (such as cancer, heart disease, stroke, orthopedics, Alzheimer's disease) are in the offing. With a growing proportion of the population comprised of minorities, greater sensitivity and focused actions directed towards those less well served by the health system will be needed. Also on the horizon are changes in the way that medical care gets reimbursed. Referred to as pay for performance in the US, the basic thrust will be to move away from a system that simply pays for more services, regardless of quality and safety considerations, to a system that rewards efficiency, safety, and high quality care.

There has been increasing awareness that the clinical environment is becoming unreceptive to clinical education and training. Because of cost containment measures and pressures on physicians to be more clinically productive, the clinical environment has become a less ideal place to learn from senior staff.[1] As a result of shorter lengths of patient stays, students and residents are frequently denied the opportunity to learn about the clinical progression, treatment, and follow up of each case. As patient throughputs increase and with patient care shifting toward ambulatory settings, new challenges emerge with respect to the type of training and the setting where it can be provided.

A little more than 5 years ago, informed citizens on both sides of the Atlantic and elsewhere were stunned to learn that medical error was a leading cause of death and injury.[5 6] In addition to safety, other dimensions of quality care—its effectiveness, efficiency, timeliness, patient centredness, and equity in terms of individuals and subgroups treated—are far from what they should be.[3] In fact, the gap between the quality received and the quality that scientific knowledge and medical technology support is so wide and deep in the US that the Institute of Medicine (IOM) best described it as a chasm. Problems associated with working conditions and work space design, misdirected management practices, neglect of the system-based interdependencies of care, staffing and scheduling issues, and failure to embrace some of the basic tenets of safety culture and high reliability organizations cause further erosions of quality and put patients at risk.[7] While training is but one of the vehicles for bringing about human performance and system based changes in health care, it needs closer examination than it has received heretofore to realize its full potential.

DO EDUCATION AND TRAINING BENEFIT FROM A SCIENTIFIC AND THEORETICAL FOUNDATION?

Not according to William James who over 100 years ago asserted:

"You make a great, a very great mistake, if you think that psychology, being the science of the mind's laws, is something from which you can deduce definite programs and schemes and methods of instruction for immediate schoolroom use. Psychology is a science and teaching is an art; and sciences never generate arts directly out of themselves. An intermediary inventive mind must make the application, by using its originality."[8]

Considering that James made that statement in 1899, he probably had few detractors. After over a century of research—starting with the early work of Ebbinghaus and Thorndike, continuing with the behavioristic psychology of the 1930s, 1940s and 1950s, and more recently with the cognitive psychology of the last few decades—the question remains whether James's statement would be considered true today. While the basic sciences are motivated by reasons other than practical application, the discipline of instructional design is concerned with identifying the conditions which lead to desired instructional outcomes and, as such, serves as a link between research on learning/cognition and instructional practice. Serving in this intermediary role, is it not fair to ask: "What has a century of intermediary activity wrought?"

Our behavioral foundations

The behavioristic psychology of the 1940s and 1950s left its mark by providing us with a relatively linear, frame based approach for controlling the instructional environment. While the advent of programmed instruction can be traced to Pressey's demonstration of a teaching machine in 1925, the movement came into its own in 1954 with the publication of Skinner's *The science of learning and the art of teaching*.[9] The behavioral dictum that "behavior is shaped by its consequences" could be demonstrated instructionally by keeping the student's immediate instructional environment—a frame of instruction—quite simple in terms of response requirements. By responding to a provided response alternative or filling in a missing answer, reinforcing or punishing consequences were made contingent upon the student's response. By starting with instructional material that was well within the knowledge repertoire of the student, the basic idea is to increase the probability of reinforcing the student's initial responses (and hence self-confidence) before introducing more difficult material. By raising the criterion for reinforcement (that is, increasing the difficulty level of the item or by increasing the number of steps required to arrive at an answer) in a graduated fashion, relatively complex sequences of behavior can be shaped. For Skinner, instructional practice is simply the arrangement of contingencies of reinforcement to promote learning. Likewise, a teaching machine is simply a device that arranges contingencies of reinforcement.

Few get excited about programmed instruction any more and Skinner's dictum has long since been overshadowed by interest in newer developments. Nevertheless, there are several instructional features that originated during this earlier period that, in our current computer and web based systems, we still like to tout. We like to subdivide our courses into small units or steps rather than hold students accountable for large blocks of instruction at a time. We like our new system to require active responses on the part of students rather than passive listening or reading. We are also very quick to point out that the new system allows students to proceed at their own pace. Further, we are not likely to forget the importance of feedback, provided immediately upon a student's response.

''Active learning'', ''self-pacing'', ''immediate feedback''—these are the golden buzz words that are used to promote today's computer driven instructional systems that have their origins in the 1950s. What is surprising is not that behavioral psychology has made lasting contributions to instructional technology, but that we so eagerly accept these principles without question. Does a student really need to be ''active'' to learn something? Under what conditions might ''inactive learning'' serve us better? Is self-pacing always the best rate at which to learn new material? When is it advantageous to alter our rate of learning? Do we always need immediate feedback for making a response? Under what conditions and for what tasks would delayed feedback or no feedback at all facilitate learning? Just because a principle becomes adopted in a practical setting does not mean we know everything about it. Unfortunately, acceptance and excessive promotion sometimes preclude the necessary intermediary application to which James alluded.

Contributions of cognitive psychology

With respect to more recent developments in cognitive psychology and information processing theory, there are several areas of research that have significant implications for the design of instruction. We have a much better understanding of the limited capacity of short term memory as an essential phase for any task that requires us to process information.[10 11] In presenting instructions, for example, we know the student will not be able to contend with more than four or five steps or operations at a time. When this amount is exceeded the student must start to selectively rehearse or chunk the information for long term storage which, in turn, limits the processing of subsequent information.[12] Other research has underscored the important role of knowledge organization or schema—that is, generic concepts stored in memory about frequently experienced situations that are used to interpret new situations and observations—in learning and problem solving.[13] The design of instructional content would do well to attend to the relationship between existing learner structures and the structure of the information to be learned.[14 15]

Research on the interplay of knowledge structure and processing abilities, for example, is pinpointing differences between experts and novices in a variety of domains—for example, interpretation of radiographs, problem solving in physics, performance of electronic technicians—with regard to how the two groups access and use an organized body of conceptual and procedural knowledge. Quite simply, the initial representation of a problem is very important for arriving at an adequate solution. Problem representation depends on domain related knowledge and the organization of this knowledge. A problem solver's knowledge determines knowledge representation which, in turn, facilitates retrieval of problem solving procedures. Gagne and Glaser note that novices are at a disadvantage in problem solving situations, not so much as a result of their inability to use problem solving heuristics or strategies but because of the inadequate state of their knowledge bases.[13]

During the process of engaging in daily tasks and interacting with objects, devices and people, individuals develop representations referred to as mental models to make sense of their immediate environments which, in turn, serve to guide their performance. In a discussion of mental models and their role in facilitating learning and performance, Gagne and Glaser provide several tactics that are worthy of consideration for the instructional setting. First, it is desirable to have an understanding of the mental model that the student is using in his or her attempt to understand the subject matter, whether it is a medical device or a patient's failing condition. Many individuals have distorted or misleading representations of the way things work. Understanding the model (albeit naive or erroneous) that students are using promotes communication and the construction of alternative conceptual representations for more proficient learning and performance. A second tactic is to track changes in use of mental models as one progresses along the path from novice to expert. We should not be surprised if we find that instructional strategies and techniques appropriate for experts will not work that well with novices. A third tactic is to build upon mental models currently in use by the student and extend their range of application and provide additional structures for organizing new knowledge. A fourth tactic that Gagne and Glaser suggest is to teach explicitly mental models that facilitate performance in specific knowledge domains.

In short, this avenue of inquiry has underscored the importance of building up knowledge structures for facilitating the student's capacity to learn new things on the basis of current knowledge. Instructional techniques for novices and less experienced personnel need to provide some of the organizational scaffolding that experts use so proficiently. A basic organizational structure provides students with a foundation of acquiring new knowledge, and enables them to begin formulating progressively more expert schemas.

Other contributions from cognitive engineering and system science with direct relevance to patient safety and quality of care have focused on the relationship between performance levels and error types.[16–19] Many of the errors that physicians and nurses make are the slips and lapses of skill based performance. Slips occur whenever there is opportunity for attentional capture through workplace distraction or preoccupation. Slips, such as giving a medication to the wrong patient, are quite unpredictable since they are thought to involve momentary interruptions of highly practiced automatic routines. Lapses are a more covert error form, usually referred to as memory failures, yet they still involve a discrepancy between what was intended and what was actually performed. When care providers fail to deliver a scheduled medication, a lapse has typically occurred. Rather than succumbing to a ''blame and train'' mentality, it makes more sense to identify and remove the environmental or organizational factors that are contributing to the slip or lapse. Further training would be of dubious value since care providers are already performing these routine tasks at asymptotic levels.

Rule based performance refers to goal directed behavior that comes under the control of stored rules (for example, if *x*, then *y*). When faced with situations for which there is no knowledge or rules to guide behavior, the required level of performance moves to a higher conceptual level and is said to be knowledge based. Errors that occur at the rule based and knowledge levels have been dubbed mistakes. Unlike slips or lapses, mistakes occur when intended actions proceed as planned; however, the intended plan, set of rules, or implementation strategy is inappropriate for achieving the objective. Mistakes or errors of judgment that are made by senior personnel and decision makers are frequently equivalent to gaps in knowledge structures. Uncritical use of heuristics and various forms of cognitive bias—for example, availability, confirmation, sunk cost—also impair knowledge based performance. Challenges to knowledge based performance become quickly evident in complex dynamic clinical environments where conditions of bounded rationality, inadequate mental models, interruptions, and the need for timely decisive action converge to test the resilient efforts of stressed provider teams. There is much we need to learn about knowledge based performance and the particular role that training can serve in trying to improve it.

WHAT IS THE SYSTEMS APPROACH TO THE DESIGN OF TRAINING?

Systems approaches to training (also referred to as instructional systems development models) evolved in the US in the late 1950s and with the conviction that an orderly approach could take the guesswork out of military training. The military services have an immense training requirement and, before this time, training was pretty much a haphazard art as it is in health care today. However, just as the design of major weapons platforms underwent a systems engineering process, so too the design of the training subsystem underwent a systems engineering process for ensuring that assigned personnel could satisfy the job requirements of operating, maintaining, and managing increasingly complex systems.[20] Training was simply viewed as a subsystem to the larger operational system.

When first introduced, systems approaches to training represented something akin to a paradigm shift in the way knowledge gets taught. An important distinction between education and training emerged. Rather than starting with generalized scholarly knowledge which traditionally gets organized into textbooks and relayed to students under the assumption that knowledge for its own sake is good, the systems approaches start with a system or organizational need, for which training has been identified as a viable solution, and then proceed to deliver a body of instruction to designated students who have a job requirement for the specified skills and knowledge.[20 21] In 1976, a five volume set of prescriptive procedures covering the analysis, design, development, implementation, and evaluation stages of the training development process was prepared by Florida State University for the armed forces to guide those personnel assigned the development of instructional materials.[22]

The quality and effectiveness of training is enhanced when there is a strong and direct correspondence between instructional content and the actual performance demands of the job. To achieve a high level of effectiveness, training has to be designed; it does not happen in a loose ''see one, do one, teach one'' fashion. In most systems models for training there is an orderly progression of at least five stages—analysis, design, development, implementation and evaluation—that attempts to ensure the effectiveness of the training.

Analysis and design

The first two stages of the systems approach to training—analysis and design—are especially important. A critical activity of the analysis stage is conducting a job and task analysis which establishes what constitutes acceptable on-the-job performance. It answers the questions: what tasks, performed in what manner, under what conditions, in response to what cues, to what standards of performance make up the job? Because of the importance of the job and task analysis for ensuring job relevance, training analysts and subject matter experts need to work together closely. In lessons learned from military applications, a common mistake is to assign too few resources to the analysis stage.[23] If subject matter experts are not well represented, technical accuracy and completeness are suspect and reviews may be conducted by personnel not fully qualified to attest to the validity of the analysis. Doing an accurate and comprehensive task analysis is a labor intensive effort; however, if it is not done right the first time, it will only have to be done a second time, which usually involves additional costs and slips in the production schedule.

The establishment of training objectives occurs in the design stage. If the training objectives are poorly defined or couched in terms that are too vague, the instructional program will lack focus. Foremost, a well stated objective specifies the desired outcomes in observable and measurable terms. It identifies what the student is to do, the conditions under which the task is to be performed, and the standard of performance that must be achieved. Such objectives aid the training developer by specifying the exact performances and knowledge the training is expected to produce. When desired outcomes are specified in observable and measurable terms, it becomes readily apparent when the training methods have succeeded, when they have failed, and when they need further development to improve their effectiveness. Criterion test items are developed to provide confirmation to students as to whether they are performing the specified terminal behaviors to the required standards called for by the course objectives. The criterion test items, in turn, guide the development of training materials. As was the case in the analysis stage, adequate attention and resources need to be devoted to the design stage.

Development, implementation and evaluation

There are likewise challenging issues associated with the development, implementation, and evaluation stages of training development. During development, a media selection process takes place that aligns available media (such as workbooks, texts, CDs, web based, simulations) with the unique characteristics of the training objectives in order to promote optimal learning. Specific development activities, of course, depend upon the media under development. Compared with other decisions, the selection of media has considerable impact on the very real constraints of time, resources, and budget. As the training is developed, it undergoes formative evaluation with small groups of representative users for the sole purpose of improving the materials. The implementation stage then affords the opportunity to evaluate the full and integrated complement of materials, instructors (if required), students, equipment, and facilities all functioning together. After the training program has been operational for a while, it undergoes summative or external evaluation. If students do not need what they are taught, or need instruction they do not receive, this information needs to be fed back to maintainers of the training system.

The training research literature is immense and there are reviews that discuss various methods and strategies, assess factors that influence training effectiveness, and examine the conditions that affect the transfer of training.[24 25] An expanded discussion of the instructional systems development model is provided by Battles elsewhere in this supplement.[26]

CAN A SYSTEMS APPROACH TO TRAINING BE APPLIED TO CLINICAL ENVIRONMENTS?

The systems approach to training in military settings has found its most frequent application to technical and equipment oriented jobs where the role of the individual has been more of an operator or maintainer of a piece of equipment. Here the end instructional products are often a set of step-by-step procedures for performing required tasks. Parenthetically, as many equipment dominant jobs become automated, the role of the individual shifts toward a monitoring function of system states. With respect to healthcare delivery, it is recognized that there are many routine clinical tasks (such as skill based medical and surgical procedures) that are subject to excessive variation and lack of standardization that could clearly benefit from a systems approach to training. In addition to excessive variation in the execution of procedures, there also are excessive gaps under the apprenticeship model in the types of cases to which residents and other providers are exposed. System approaches to training can fill these gaps.

At the same time, as the role of the individual becomes that of a problem solver encountering unfamiliar, uncertain, or highly fluid situations as would occur in an emergency department or intensive care unit, a traditional systems approach is best supplemented by cognitive engineering approaches that strive to gain an understanding of the knowledge based structures and cognitive processes underlying skilled performance. Because of the complexity, uncertainty, and rapidly emerging conditions in many clinical settings, it is unlikely that a finite set of step-by-step procedures will be robust enough to be useful in many circumstances.

Several investigators have commented on the folly of relying on written protocols in response to aberrant conditions that can arise in complex sociotechnical systems.[27–30] Cook and Woods note that normative models of task performance assume that complete knowledge of how problems should be solved is available, which is rarely the case;[27] Reason asserts that there are not enough trees in the rain forests to satisfy all the procedures necessary to guarantee safe operations;[28] and Vicente recounts an amusing tale when operators in a nuclear power plant decided to ''maliciously comply'' with written emergency procedures during a simulated test and found themselves stuck in an infinite loop of repeating the prescribed actions.[29] Weick also underscores the difficulty of writing procedures that anticipate all the anomalous conditions that can adversely impact people at work and instead urges a commitment to resilience—a property found in high reliability organizations that encourages people to take advantage of swift negative feedback and engage in real-time learning in response to unfolding unexpected events.[30]

Bounded rationality

A similar and more realistic shift in thinking with respect to decision making has occurred over the past few decades. Traditional rational models of decision making are based on a set of assumptions that prescribe how a decision should be made—for example, define the problem, identify the criteria, weight the criteria, generate alternatives, rate each alternative on each criterion, and compute the optimal decision—rather than describing how decisions actually are made.[31] However, investigators who have originated descriptive decision making models maintain that individual judgment is bounded in its rationality and that decision making can be best understood by explaining actual processes rather than a normative approach that prescribes what should be done.[32 33] While individuals may like to view their decision making as rational, a bounded rationality framework informs us that, in many settings, the problem space is very complex, essential information is lacking, competing trade-offs among alternatives exist, perceptual and attentional limitations in working memory exist, tasks need to be executed quickly, interruptions and background noise are omnipresent, and economic constraints further curtail the amount of time that can be spent on each problem. Taken collectively, these limitations often prevent decision makers from making optimal decisions. Instead of examining all the alternatives and deriving the best solution, decision makers simply arrive at a solution considered reasonable or acceptable given the circumstances—that is, they *satisfice*.[32]

To decide or to recognize

Field research on how those in high stake occupations such as fire fighters, combat personnel, and paramedics make decisions suggests that experienced decision makers do not deliberately follow a step-like rational model of generating and rating alternatives, but instead use recognitional strategies whereby elements of a situation that have been experienced previously are recognized and responded to accordingly.[34 35] With novices, the use of recognition based decision making does not occur that frequently. Such findings are congruent with research on expert-novice problem solving differences with respect to domain-specific knowledge.[36] The use of quickly targeted solution methods is a major characteristic that distinguishes experts from novices. This has become especially evident in high stake occupations where skill automaticity or second nature swiftness with which expert performance takes place is critical. Cognitive task analysis procedures and knowledge elicitation techniques have extended our understanding of the tacit knowledge underlying skilled performance that experts themselves have a difficult time making explicit.

Where does this leave us in terms of our original question: ''Can systems based approaches to training be used effectively for the clinical setting?'' To be sure, there are many clinical procedures that are not being performed correctly or not being performed at all because of lack of knowledge and lack of practice as well as for other reasons. Excessive variation of practice remains a large problem. Providers who perform these procedures could benefit from a systems approach to training. One of the reasons why training traditionally has been considered a weak kneed solution for behavioral change (an old human factors bromide has it that ''it is easier to bend metal than twist arms'') is that so much of it has been designed, developed, and implemented so poorly. Re-occurring challenges are identifying what is actually learned and to what extent the newly acquired behaviors actually transfer to the job site. The military services, on the other hand, take training very seriously and have spent considerable research and development resources during the past six decades on developing effective and efficient training approaches. Health care would do well to examine these systems based approaches seriously. At the same time, as researchers sharpen our understanding of the complexity, fluidity, uncertainty, and unique conditions that characterize many clinical environments and the way in which information is processed and decisions are actually made, system based training approaches will need to accommodate these new insights. Because of the unpredictable nature of clinical work in highly demanding and fluid environments, it is unreasonable to expect that tasks can be or should be executed in the same manner, under the same conditions, to the same standards of performance as traditional systems approaches to training imply.

IS MEDICINE TAKING ADVANTAGE OF NEW EDUCATIONAL AND TRAINING INNOVATIONS?

Like many disciplines, new ideas and the shifting of scientific and professional paradigms have not come easily to medicine. While Flexner's ground breaking report shortly after the turn of the 20th century on sham and fraudulent practices in medicine stunned the public and had a profound impact on the profession, Codman had a more difficult time in subverting the prevailing ''physician as individual craftsman'' paradigm in advocating that physicians and hospitals judge the success and failure of their efforts by keeping records of direct patient care outcomes.[37–41] It was not until the 1980s that the lessons imparted by Codman started to take hold in the form of evidence based medicine.[41]

In a similar vein, earlier periods of medical education are frequently characterized as relying too heavily for too long on outdated pedagogical methods such as memorization of lecture content. However, it would be a mistake to assume that medicine has not attempted to take advantage of new educational and training advances. One can always question the pervasiveness of these new pedagogical insights and whether they have migrated sufficiently from major medical schools to other venues of healthcare delivery. Nevertheless, Papa and Harasym provide an informative overview of medical curriculum reform in North America, starting in 1765 with the apprenticeship based curriculum model and progressing through discipline based, organ system based, and problem based curriculum models and up to the present with the clinical presentation curriculum model.[42] In addressing the underlying educational principles and practices of each model, medical education researchers have availed themselves to the research literature and theoretical perspectives of cognitive science to push for more robust reform.

Curriculum reform

Over the years, adult learning theorists have incorporated behavioral and cognitive principles in their guidance to educators who, in turn, were receptive to the notion that learning is a lifelong process, that it should be student centred rather than instructor centred, and that it should focus on active learning whereby students interact with the content to be learned in realistic scenarios and problems. It was also recognized that students learn from their peers, especially those in other disciplines, and thus cross-disciplinary interactions in small groups would help prepare students for the necessary teamwork that demanding clinical environments were making increasingly evident. The problem based curriculum model with its focus on imparting content in the context of clinical problems made good use of these principles. In addition to creating a more engaging learning environment for students, it was also assumed that repeated exposure to clinical problems would enhance students' hypothetico-deductive reasoning, considered an essential ability for acquiring clinical expertise.[42 43]

However, it was not long before the assumption that clinical expertise derives from a generic problem solving ability met with serious resistance. Other investigators provided evidence for the view that diagnostic performance instead depends upon the development of knowledge specific to each clinical presentation.[44] Given evidence that demonstrated that clinical expertise is dependent upon knowledge structures specific to a particular presentation (for example, chest pain) as well as the deployment of task specific cognitive processes, the utility of a generic problem solving process becomes more difficult to maintain.[42] The clinical presentation model thus builds its curriculum by identifying and exposing students to all the common and important ways patients may present, given the medical specialty area.

It should be noted that the curriculum changes to which Papa and Harasyn refer pertain, for the most part, to the preclinical years of medical education. Clinical acumen is acquired during clinical rotations and graduate medical education/residency training. When one discusses the need for curriculum reform and new models for learning, we also need to be aware of some of the challenges, inefficiencies (for example, using trainees to perform mundane tasks known as scut work which do not promote the learning of particular clinical skills), and areas in need of improvement during the latter years of clinical training.

Embracing new training technologies

Recent years have seen advances in the use of computer driven technologies for the training of clinical skills. Simulation is probably the best example. Compared with other high risk industries, medicine has been late to take advantage of the benefits that simulation offers. Such benefits include a safe practice environment (real patients do not need to be harmed), ease of availability, control of training conditions to promote learning, over-learning of intricate procedures, and integration of resource management skills in team settings. As mannequins have become more sophisticated and realistic in terms of underlying physiology, vital signs, and pharmacological effects, and as curriculum developers become more skilled in the appropriate use of simulation as part of the overall curriculum, there is reason to believe that the way tomorrow's physicians and surgeons are trained will be undergoing dramatic change.

Perhaps most telling in this regard is a recent ruling by the US Food and Drug Administration (FDA). In the spring of 2004, evidence was presented to the FDA attesting to the effectiveness of virtual reality based simulation for skills training and assessment.[45] In April 2004 the FDA voted to approve the very intricate carotid stent procedure that included simulation based training. In other words, for physicians to perform the risky procedure, they would have to demonstrate their competency on the simulator in accordance with established training criteria before they would be permitted to perform the procedure on patients. Scerbo justly notes that the FDA's actions are unprecedented, representing "the first time in the history of medicine that a performance based competency measure will be used to determine who can and cannot perform a medical procedure."[46]

Web based modes of instruction, sometimes treated interchangeably with "e-learning" or "distance learning," represent another technological opportunity that has spurred the interest of medical educators. Within the past decade, hundreds of major US universities—both undergraduate and graduate programs—have invested heavily in creating web based infrastructures and in training their faculties in converting lecture based materials to an electronic format. It is not unusual to find students from globally dispersed locales in South Korea, England, India, Australia and the US enrolled in the same course and working on assignments and projects in virtual team settings. Medical schools and professional medical associations are starting to employ these same modes of instruction. Of particular note is the development of a web based patient safety and quality improvement program by the American Board of Medical Specialties to enable its various specialty board members to meet requirements for maintenance of certification.

None of these educational and training technologies in and of themselves will create new learning miracles. While this should be somewhat obvious, it nonetheless needs to be said. They all require a dedicated human component—educators, technicians, and managers—to support the necessary front end analysis, development, implementation, evaluation, maintenance, and sustainment that such technologies entail. For example, creation of a simulated operating room not only involves the cost of sophisticated mannequins, equipment, and associated devices, but also requires the physical space that will house the simulation, technicians to keep all the components running smoothly, faculty trained in simulation techniques and debriefs, and administrative assistants for scheduling simulator sessions and keeping track of student performance records. Likewise, web based courses not only require dedicated servers, but also faculty trained in the new educational medium, students oriented to the new mode of learning, technicians and technical support personnel, and administrators who set course standards and monitor the quality of the overall educational program. As is the case with any technological application, educational and training

Key messages

How is the practice of medicine changing?

- Rapidly expanding scientific, economic, and demographic changes underscore the need for a systematic approach to training.
- Cost containment and productivity pressures on clinicians make the clinical environment less than ideal for training.

Do education and training benefit from a scientific and theoretical foundation?

- Research contributions from behavioral and cognitive psychology enable instructional designers to effectively design the instructional environment and understand student knowledge structures that facilitate new learning.
- Instructional design serves an important intermediary link between basic research on learning/cognition and instructional practice.

What is the systems approach to training?

- It begins with a system or organizational need for which training of individuals is considered a viable solution.
- It involves at least five primary stages: analysis, design, development, implementation, and evaluation.

Can a systems approach to training be applied to clinical environments?

- It can reduce excessive variation in the performance of many routine medical and surgical procedures and address deficiencies resulting from lack of exposure.
- For work in highly fluid, complex, and uncertain clinical environments, a systems approach should accommodate needs for resiliency and recognitional approaches to decision making.

Is medicine taking advantage of new educational and training technologies?

- Learning is viewed as a lifelong activity in medicine and health care.
- Simulation and web based approaches address the training needs of adult learners but, to be effectively implemented and sustained, require dedicated designers, faculty, technicians, and administrators.

innovations require the intelligent and dedicated effort of a multidisciplinary group of individuals and strong management support if they are to be implemented effectively and sustained.

CONCLUSIONS

This paper touches on some of the issues that need to be addressed in the design of training. Many of the fundamental issues which have been neglected in health care remain with us as tomorrow's challenges. The following five fundamental issues that need clearer articulation have been discussed:

- understanding the nature of the training requirement—that is, how the practice of medicine is changing;
- gaining an appreciation of the scientific and theoretical contributions from the behavioral and cognitive sciences that underlie curriculum reform and training innovations;
- realizing that there is a systems approach to the design of training that eliminates much of the guesswork, subjectivity, and uncertain outcomes;
- acquiring an understanding of the strengths and limitations of how a systems approach to training can be applied to clinical settings; and
- understanding how medicine is currently taking advantage of curriculum reform and new training technologies.

It is hoped that framing the issues along the lines summarized in the key messages box represents a good first step towards realizing the full potential that a systems approach to training as well as educational and technological innovations have to offer.

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