

# Thoughts about the Future of Modeling and Simulation in Healthcare and Higher Education

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**Abstract-** The U.S. healthcare and higher education systems face long-standing challenges concerning effectiveness and cost-effectiveness that could be addressed by modeling and simulation. This will require the modeling and simulation industry to adapt through diversification, experimentation and the engagement of the leaders of these systems in effecting solutions.

**Keywords-** U.S. Healthcare System; U.S. Higher Education System; Modeling and Simulation; Business Competitiveness

## I. INTRODUCTION

This article addresses the systems of healthcare and higher education in the U.S. and the role that modeling and simulation is currently playing and could play in the future. Modeling and simulation refers to a toolkit of techniques wherein human actors and/or computer programs imitate real world processes and systems through time. Modeling and simulation applications are used to improve understanding, training, decision-making and assessment of performance in practice. My particular interest concerns how modeling and simulation can help ensure that we have the most effective and cost-effective healthcare and higher education systems in the world. After all, the quality of the education and healthcare systems are essential foundations for the competitiveness of the national economy.

There is a clear need for the modeling and simulation industry to diversify, to experiment and to expand its networks of professionals and customers. It is also important to engage those organizations and associations that are actively trying to educate public and private sector leaders about the tremendous potential of modeling and simulation. Organizations such as the National Training and Simulation Association, the National Modeling and Simulation Coalition, the Society for Simulation in Healthcare, and the National Center for Collaboration in Medical Modeling and Simulation deserve support and active participation.

That most gentle of Roman emperors, Marcus Aurelius, noted that we should:

*Examine into the quality of the form of an object and detach it altogether from its material part; and then contemplate it; then determine the time, the longest which this peculiar form is naturally made to endure.*

This article discusses the current state of the American healthcare system and, to a lesser degree, the American system of higher education. Some observations about the organization and focus of the modeling and simulation industry in the U.S. are then shared. Finally, issues affecting the future development of the industry are identified.

## II. HEALTHCARE

The healthcare system in the U.S. is the largest in the world. It currently consumes approximately 17% of GDP, amounting to almost \$3 trillion [1, 2]. This is a mind-boggling amount of money that is spent on healthcare. It is particularly so when one considers the fact that this \$3 trillion amounts to one half of all of the money spent in the world on healthcare and that the spending only covers 5% of the world's population [3]. Further, this level of spending is 50% higher than the per capita spending by any other developed country [4]. Projections are that this level of spending will grow to somewhere between 25 and 30% of GDP by 2030 [5]. If one has confidence in more distant financial projections and if no substantive changes are made in healthcare delivery, then the health industry's share of GDP approaches 50% by 2080 [6].

This projected growth in spending is unsustainable. In spite of the highest spending in the world, the U.S. healthcare system doesn't rank Number 1 in the world on any healthcare outcome measure. Indeed, the U.S. ranks 36<sup>th</sup> for life expectancy, 39<sup>th</sup> for infant mortality, and 42<sup>nd</sup> and 43<sup>rd</sup> respectively for adult male and female mortality [7].

Describing healthcare in the U.S. as a system is analogous to drawing boundaries around a series of independent organizations and professionals and then labeling the result a system. A more accurate description would be to describe healthcare in the U.S. as an amalgamation of professionals, provider organizations, insurers and patients. There are currently about 1 million physicians in the U.S., 3 million nurses, and 5 million allied healthcare workers of one sort or another [8, 9, 10]. These professionals work in a bewildering array of organizations, including 500,000 medical offices, 5,800 hospitals, 16,000 nursing facilities, 180,000 laboratories, 1,100 community health centers, and 2,800 local public health departments to mention just a few of the types of settings where healthcare is delivered [11, 12, 13, 14, 15]. Some of these settings are organized into academic health centers and regional healthcare systems, but most are either loosely linked or independent.

The unacceptable cost and outcomes of the current healthcare system in the U.S. become even more troubling when one considers the impact of the 70 million aging baby boomers. Most of them will live another 30 to 40 years and undoubtedly develop one or more chronic illnesses that will require both the occasional acute intervention and long-term management. Coupled with a bolus of aging baby boomers, the U.S. is currently experiencing a nearly irreversible obesity epidemic that will inevitably be followed by an explosion of cardiovascular and metabolic diseases.

As if these problems weren't daunting enough, there is the problem posed by emerging diseases. In the last 20 years, 16 emerging diseases and 5 reemerging pathogens that threaten the health of the world's population have been identified [16]. Many of these diseases and pathogens have their origin in the encroachment of humans into sparsely settled regions of the world. The reality of global travel, effective disease dispersion vectors such as food, water and insects, and the increasing interconnectedness of people worldwide require widespread surveillance and rapid interventions from a healthcare system that is oriented to the provision of personal health services.

Unfortunately, even this catalogue of maladies does not fully capture the challenges facing the U.S. healthcare system. Each year the medical device industry introduces 50 new high-risk devices and approximately 4,000 moderate and low risk devices into the healthcare marketplace [17]. The pharmaceutical industry introduces 80 new or repurposed medications and 30 new biologics every year [17]. So, over the course of a 30-year professional practice, physicians and other health professionals are faced with the daunting challenge of understanding an unending array of new medicines and techniques and making appropriate use of them in the care of their patients. Keeping up with this level of constant innovation would be hard enough if all of the practitioners worked within an academic health center where the discovery and dissemination of information and the incorporation of innovation into professional practice is the *raison d'être*. Outside of academic health centers, practicing professionals do have intermittent access to continuing education programs, but not necessarily to the training that would assure continuing competence and high performance.

In recent years, analysis of the performance of the U.S. healthcare system has identified a series of issues related to patient safety. Provider organizations such as hospitals have responded by developing policies, procedures and training programs to improve patient safety. The initial study by the Institute of Medicine in 1999, *To Err is Human*, indicated that there were about 100,000 deaths a year due to patient safety errors [18]. Recent analyses suggest that, in spite of all of the policies, procedures and training programs that have been implemented in the past decade, serious patient safety problems persist. Issues such as retained objects, air emboli, blood incompatibility, catheter infections, pressure ulcers, vascular catheter infections, surgical site infections, falls, and poor management of blood sugar levels continue to be unacceptably high. Approximately 70% of patient safety issues are a result of delay in diagnosis, medication errors, the care management process and falls [19].

As Marcus Aurelius would observe, the U.S. healthcare system has endured as long as this peculiar form is made to endure. The combination of extraordinarily high costs, less than stellar outcomes, and persistent patient safety issues suggest that the analytic techniques of the modeling and simulation industry have a target rich environment to offer products and services that can have a positive impact. That said, the modeling and simulation industry must choose to enter the market more broadly and must do so with a new business model. We will return to this point later in Section IV.

### III. HIGHER EDUCATION

The U.S. higher education system is widely recognized as the most successful in the world. The U.S. excels at providing broad access to institutions of higher education and producing students who have the capacity for lifelong learning and for innovation. Yet, there are ongoing concerns about the performance in practice of graduates. There are 4,500 degree granting institutions in the U.S. [20]. There are 2.5 million full-time employees and 1.4 million part-time employees [21]. In recent years public support for higher education at both the federal and state levels has declined. The cost of providing education; however, has not declined. So, as a result tuition and fees have increased and student debt has exploded. Today, there are about 21 million students enrolled in the U.S. higher education system [22]. Their average debt upon completion of their studies is \$27,000 and the total outstanding debt is one trillion dollars [23, 24]. Debt for medical students now totals over \$2 billion and averages over \$160,000 per student [25].

When one focuses on higher education programs in the medical and health professions, the datedness of the overall structure of the approach is striking, particularly in medicine. In 1995 Christakis noted that: "*For nearly a century...the reports suggesting reform of U.S. medical education have been strikingly similar in structure, content and tone.*" [26] In other words, nothing much has changed in medical and health professions education, although health professionals practicing in the early years of the 20<sup>th</sup> century would scarcely recognize contemporary healthcare delivery.

Changing the process of medical education is notoriously difficult. That difficulty pervades the other health professions as well. Change is so difficult and progress so slow because of several driving forces that underlie the process and content of health professions education. These factors include professionalism, professionalization, the emphasis on individual competence, the nature of academic enterprises, proprietary technology, and an anticipatory approach to risk management, and are illustrated in Figure 1. So thoroughly ingrained are these factors and so pervasive is their influence that proposals for change in the health workforce that do not address them will simply fail, as they have so often in the past. For today's discussion, I want to focus only on the first four factors that constrain the education of medical and health professionals.

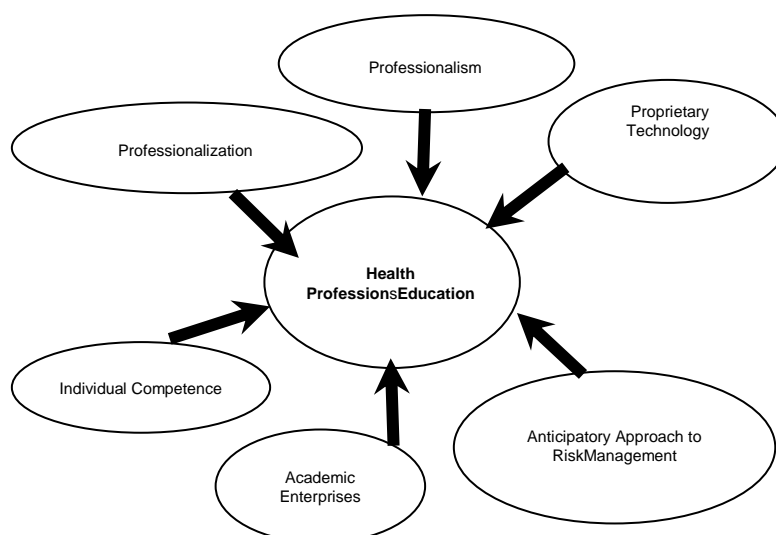


Fig.1 Basic Factors Driving Health Professions Education

### A. Professionalism

Professionalism implies the process of a group of individuals setting themselves off from others on the basis of values and expertise. This is usually accomplished by identifying a discrete body of knowledge, a code of acceptable behavior, a defined scope of practice, a process of internal review and certification of the competence of the group members, a process for remediation of members whose competence fails, and a commitment to continuing education and continuous improvement. Most healthcare delivery involves interaction between practitioners and patients in a private encounter where the patient is at a disadvantage in terms of knowledge and his/her health status at the time. Given this clinical context, professionalism has long been identified as the best means of assuring the quality of the practitioners who deliver healthcare [27].

In general, this concept has served the healthcare system well. However, critics are correct to note the limitations of professionalism. The process of setting a group apart from other groups inevitably involves a sense of tribalism, a too keen sense of who belongs and who does not, coupled with all the sorts of group building behaviors—separate uniforms, different titles, different status, defining exclusive areas of practice, profession-based recognition for career advancement, etc.—that make working well with other types of professionals a secondary concern. The process of self-policing is too often compromised by the urge to maintain the status and image of the profession at the expense of allowing less competent or incompetent practitioners to continue to be members of the profession in good standing. Too often, the process of continuing education is linked solely to hours spent in educational sessions and not to the demonstration of continuing competence in practice. Indeed, this combination of limitations creates concern about whether the benefits of professionalism are beginning to be eclipsed by its costs. Unfortunately, the professionalism of individuals often impedes their capacity to work effectively in teams whose members have different competencies and whose work together is a more important determinant of success than the work of any single member of the team [28].

Political and social proposals for reforming healthcare delivery systems include incentives for new models of care that change and blur traditional professional roles. Based on the formation of collaborative teams, healthcare systems will be managed through shared information and will be incentivized to address the full continuum of care. Established notions of professionalism, including the dominance of the health practitioner, are pushed into the past by the networks and rapid communication systems that now empower patients to engage in shared decision-making and to be at the center of managing their own health [29].

### B. Professionalization

Professionalization refers to the process of developing public recognition and sanction of a group of similarly trained individuals as a bona fide profession. Typically, the best measures of success in becoming recognized as a profession are that a group adopts national training standards for entry into the profession; uses national tests to certify that the standards are fulfilled; and then employs the standards as the basis for a scope of practice that defines what the group members can do and as the legal basis for licensure, certification and practice. This process is inevitably political and often highly confrontational. Disagreements over the boundaries of scopes of practice between physicians and advanced practice nurses and between groups that already have a legally sanctioned scope of practice and any group of new practitioners who attempt to establish a new, related scope are often among the most contentious battles that occur in state legislatures.

Professionalization has its benefits—clearly stated standards concerning who can do what, public accountability for professional licensure and practice, public reporting of sanctions levied on errant practitioners, and a rigorous path that must be followed to achieve public recognition. Once again, however, the costs are becoming more apparent [30]. Professionalization

reinforces the individuality of practice and responsibility and does not often address interprofessional teams, the flexibility of roles inherent in teamwork or shared responsibility. Legal definitions of scopes of practice often lag, and sometime lag considerably, the knowledge and capabilities of practicing health professionals. Decision-making bureaucracies are often dominated by the regulated professions and slow to change. They are also not oriented to facilitating shared accountability among the interprofessional teams that constitute much of healthcare practice. Necessary improvements in practice that are identified on an everyday basis are often stymied because they conflict with standards and scopes of practice that have lost their relevancy. The main concern is not that bureaucrats are incompetent because they rarely are; rather, the concern is that the practice world is now changing much faster than the professional regulatory process can accommodate. The resulting gap creates legal and financial risk for those who seek to innovate.

### *C. Individual Competence*

The practice of healthcare involves a variety of individuals with differing levels of education and training. From certification to graduation to licensure and recertification, the focus of the legal and professional regulatory system is on the individual [31]. Proof of competence has historically been based on the successful completion of a course of study ranging from some months to as many as eleven years of post-collegiate study; the successful completion of national and/or state exams; and some process of continuing education that may or may not involve a periodic re-examination by either the state, the profession or both. This process of demonstrating competence holds true generally for laboratory technicians, physical therapists, pharmacists, dentists, nurses, physicians, administrators and the manifold public and allied health workers who together constitute the U.S. health workforce. Recent innovations in the process have often focused on ways of assessing continuing competence in practice in addition to assessing the knowledge base [32]. Innovations have arisen from concerns about the capacity of practitioners of all types to be knowledgeable about the plethora of emerging diagnostic and therapeutic technologies and about their ability to continue to practice effectively during decades-long careers.

Effective processes for assuring the continuing competence of individuals is, of course, necessary for maintaining the quality of the U.S. healthcare system. As many observers have noted, however, individual competence is not sufficient to ensure either patient safety or high quality patient care [33]. The ever-increasing specialization of knowledge, the practical limits on how many hours a week can be worked safely, and the fact that patient health problems require competencies held by practitioners of different professions combine to require additional competence in working as a member of a team [34]. Communication, cooperation, and the recognition and integration of disparate skill sets along with patience, perseverance, and shared responsibility and accountability are central attributes of effective team members. Many reform proposals over many years have urged medical and health education programs to do a better job of incorporating these concepts into their curricula. Similar calls for professional certification, licensure and recertification programs to incorporate an emphasis on interprofessional teamwork have not been heeded [35].

Unfortunately, the striking similarity of educational reform proposals demonstrates that only minimal changes in the process of medical and health professions education have occurred during the past century [36]. Until individual competence is supplemented by team competence, both in education and in certification, the types of quality and safety problems that have been well documented in the U.S. healthcare system are inevitable. That many organizations involved in healthcare delivery—hospitals, group practices, insurers—are beginning to force change by requiring evidence of team competence as a condition of the right to work and to be reimbursed in particular settings is again evidence of how the professional societies, the educators and the regulators lag real world practice.

### *D. Academic Enterprises*

Medical and health professionals are still generally trained in formal academic programs designed according to the model described by Abraham Flexner over a century ago. A rigorous acquisition of scientific knowledge gained through a lengthy and costly course of study is followed by years of shadowing and emulating established practitioners, generally within the context of an academic setting. Progress through the training program is gained by the demonstration of the capacity to pass difficult cognitive exams and to provide clinical care that meets the standards of the clinical faculty. The tenets of professionalism and professionalization are both explicit and pervasive in these academic settings, reinforcing a rigid departmental structure and tribalism that are often unproductive in the contemporary world of healthcare delivery.

The substantial public research funding of biomedical research that began after World War II was supplemented by an explosion of public financing of healthcare services in the mid-1960's through Medicare and Medicaid. One of the results of this infusion of funding has been that previously small medical and health professions education programs have grown into today's large, complex university and academic health center programs. These institutions have greatly expanded the armamentarium of health professionals, regularly adding to the available diagnostic and therapeutic tools and unquestionably improving the quality of patient care. At the same time, their size, departmental structure and complex mission requires that a

Considerable amount of their institutional effort be directed to their own growth and survival. In turn, this effort tends to reinforce specialization, a separation from community practitioners, and a 19<sup>th</sup> century conception of individual advancement in the professions. Once again, Marcus Aurelius urges us to ask how long this peculiar form of medical and health professions education can endure.

#### IV. MODELLING AND SIMULATION

The opportunities where a systematic deployment of modeling and simulation could have a positive impact are widespread. Two examples will serve to illustrate this point. First, almost every study of organizational performance notes that the most common complaints are insufficient communication and ineffective teamwork. Yet, the education system continues to focus almost exclusively on individual competence, which is necessary, but not sufficient, for productive teamwork to occur.

In the 1970s the Singer Corporation initiated an advertising campaign based on the theme: *We understand how important it is to listen*. The research underlying the campaign noted that there are four basic communication skills listed in order of their prevalence of use: listening, speaking, reading and writing. The research also indicated that the education system, when it addresses communication skills at all, addresses them in the reverse order: writing, reading, speaking and listening. This gap between how communication is taught and how it is employed in the world of professional practice presents an opportunity for modeling and simulation. Indeed, the development of standardized patients and their deployment in teaching medical and health professions students to conduct interviews, take histories and interact effectively with patients clearly demonstrates the potential positive impacts that a more widespread use of modeling and simulation could have in improving the connectedness between education and professional practice.

Another illustration concerns the fact that many hospital executives report that they spend about \$80,000 on-boarding each newly hired nurse. Most nursing education programs moved decades ago into university-based programs with occasional rotations in private professional practice settings. These programs educate knowledgeable nurses, although they lack the contextual knowledge and skills to immediately enter professional practice. As a result, hospitals are finding that they have to spend considerable resources in training nurses how to practice in their particular setting with their specific standard operating procedures and their need to maintain compliance with various public and private regulations. Simulation programs are just beginning to be developed to shorten the transition training that is required to transform well-educated nurses into high-performing nurses in their various professional practice locations. Much remains to be done.

The organization of the modeling and simulation industry reflects the fact that the vast majority of businesses that have modeling and simulation as a substantial component of their enterprise are in three fields: aviation, defense and homeland security. A distinctive model of product development and marketing characterizes these three domains. These three industries tend to follow a model that begins with a specification of requirements that is modeled on the process used by the Department of Defense (DOD). In that model, the various commands have within their purview procurement organizations that specialize in the detailed specification of functional requirements for the products that the DOD proposes to purchase. Frequently, when the requirements are completed, the DOD allocates funds to two or three competitors to conduct the research and development that will lead to products that meet the requirement. When the competitors have functional products, the DOD measures their performance against the requirements and generally chooses one company to proceed to production under the terms of a blanket purchase order for a set number of products over an extended period of time. Thus, the market is centralized, dominated by a single purchaser that defines the requirements, provides research and development funds and, ultimately, purchases the resulting product. That market model is markedly different from the higher education and healthcare domains.

Both healthcare and higher education are decentralized markets. The professionals in those domains tend to identify their requirements for products and services somewhat more generally than the DOD and they most assuredly do not provide research and development funding to companies that want to sell their products and services. Rather, they proceed in one of two ways. First, professionals in leadership roles in the various healthcare and higher education organizations identify an off-the-shelf product or service that meets their needs (based on specifications of varying sophistication) and purchase it. Second, these leaders respond to targeted marketing by businesses that have developed products and services. The facts that these newer markets work very differently from the defense market and that most of the companies in the modeling and simulation business have grown out of the defense, homeland security and aviation industries and under the government acquisition model present challenges that must be addressed.

The basic business model that is required for modeling and simulation companies that want to expand their sales into other commercial areas is one that begins with asking three basic questions. First, what are the problems that top the list of healthcare and higher education leaders? Second, what existing capabilities suggest that the company might be able to respond effectively to those problems? Third, how can the industry make the argument that modeling and simulation can improve learning, improve performance, increase patient safety and improve cost effectiveness? As the poet Ezra Pound noted: "Here error is all in the not done, all in the diffidence that faltered." The modeling and simulation industry must ask these questions and must solve these problems in new ways. Along the way there will clearly be pathways to profitability.

#### V. CONCLUDING THOUGHTS

I want to conclude by offering a simple, straightforward strategy for modeling and simulation businesses to expand their reach into the domains of healthcare and higher education. My observations have been intended to make the argument that the existing forms of healthcare delivery and higher education in the U.S. are expensive and underperforming. Further, I believe the modeling and simulation industry can make material contributions that will make higher education more effective and relevant to the professional practice communities and that will make healthcare more effective and more cost-effective.

To take advantage of this opportunity, modeling and simulation businesses must diversify their talent pool and their understanding of how products and services are developed and sold. They must experiment with repurposing existing capabilities to meet clearly identified problems in different markets. They must build new networks. This is perhaps the most critical aspect of expanding the modeling and simulation industry in the near and midterm future. Industry leaders must learn how to talk with more people from more industries than they currently do. They must think more broadly about how they can leverage the knowledge, skills and talent that they have to help others meet their performance objectives.

The Chinese poet Lao Tzu wrote that: “In action it is timeliness that matters.” The time for the modeling and simulation industry to look beyond the defense, aviation and homeland security domains is now. The efforts of the National Training and Simulation Association, the National Modeling and Simulation Coalition, the National Center for Collaboration in Medical Modeling and Simulation, the Society for Computer Simulation, the Society for Simulation in Healthcare, and other industry groups are important assets in this transition phase.

My charge is twofold: follow the Singer admonition to understand how important it is to listen *and* actively engage leaders across the healthcare and higher education communities to identify the broad spectrum of issues that modeling and simulation can impact positively.

The time for action is now. Industry leaders must change what they think about and what they do. And, in so doing, industry leaders should follow the advice offered by William James:

“In the acquisition of a new habit, or leaving off of an old one, we must take care to launch ourselves with as strong and decided an initiative as possible; never suffer an exception to occur until the new habit is securely rooted in your life; seize the very first possible opportunity to act on every resolution you make, and on every emotional prompting you may experience in the direction of the habits you aspire to gain.”

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