A Path to Better Healthcare Simulation Systems: Leveraging the Integrated Systems Design Approach

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Summary

This paper addresses the necessary steps in the design of simulation-based instructional systems. A model for designing instructional systems is presented which stipulates that the outcome metrics be defined **before** the simulation system is designed. This ensures integration of educational objectives and measures of competency into the design and development process. The paper ends with a challenge to simulator users and instructors: become involved in the integrated system design process by the daily collection of standardized data and working with the simulation engineers throughout the design process.

Introduction

Users approach healthcare simulation systems with expectations of reliability, validity, and flexibility established in part from interactions with other products and simulator systems. Successful experience with other systems is the result of following a system development process grounded in science and empirical research.

The use of simulator systems for training has a well-established history in a variety of domains including military strategic and tactical command operations,[1] managerial decision-making,[2] processing plant operations,[3] space flight operations,[4] and driving.[5] This is particularly true in aviation where flight simulators have been in use for over 100 years.[6] Consequently, the methods, procedures, and processes for creating successful simulator training systems in many other disciplines have had years to evolve and become refined.

Background Definitions and Scope

Fundamentally, a system can be thought of as an interacting combination of people, materials, tools, machines, software, facilities, and procedures designed to work synergistically for a common purpose.[7] Healthcare, by definition, is a system and comprised of many systems within systems. Simulation, as used in healthcare training, has been described as a technique that can replace or amplify real clinical experiences with guided experiences.[8] In a simulation system, therefore, these elements are *designed* to work together to substitute or enhance real experiences with guided experiences.

Designing systems

Three aspects of designing simulator systems have been articulated: 1) the process of how the system is designed, 2) the philosophy or the conceptual framework of the design, and 3) the architecture or specification of the structure of the system.[9] The design process must be applied to a simulation system and to systems in which simulations are embedded (e.g., simulation facilities), or in actual work areas (e.g., an operating room or ICU).

From a general point of view, simulation has three aspects to adjust. Each aspect provides an opportunity to enhance efficacy: 1) The simulator/technology with its peripheral components; 2) the environment, including participants, where simulation takes place; and 3) the infrastructure and tools which supports the learning environment. To determine the optimal setting for all three aspects requires an integrated simulation systems development process that addresses the whole system: not only where training takes place, but also where the skills will be applied.

Instructional Systems Design

There are many ways to develop training simulators, but to be effective they all depend upon a **prior** systematic analysis of training **needs,** the **learners,** and the training **environment**. Without the instructional front end, simulator developers lack the information required by their system engineering design models. Many professional instructional designers presently follow the Interservice Procedures for Instructional Systems Development (IPISD) model described by Branson et al.[10] In general, the process includes five major phases shown in the left-hand side of Table 1. Recently, Salas et al.[11] included a sixth step called "Transfer", which addresses the organizational support following training, recognizing the impact of the organization to facilitate or thwart a trainee's attempt to use their new skills back on the job.

It should be noted that daily clinical practice of diagnostic inquiry to inform treatment actions are very similar to the comparable manufacturing "practice" known as ***"Instructional Systems Design"*** used to provide products and services desired by customers and consumers. Clinicians will readily grasp the concept, hence the value of the Integrated Design method, once they appreciate how familiar they already are with the six steps, even if the language appears unfamiliar (see Table 1).

Building a simulator training system is a multidisciplinary effort. Indeed, it requires an **integrated systems design** approach.[12] Systems analysts, designers, and engineers are necessary but not sufficient. The design team should also include subject matter experts, instructional designers, human factors engineers, and especially user/trainee representatives.

The needs analysis can be targeted to the organization, the individuals, as well as the jobs/tasks, and it should reveal the overall educational objectives or mission.[13,11] Once the overall objectives have been identified and agreed upon, subsequent analyses are performed which address the specific tasks, users or trainees, and specific training needs using specific methods such as hierarchical task analysis, cognitive task analysis, and critical decision methods. In addition, the trainee population is often analyzed to determine the existing levels of knowledge, skills, and abilities, and those that need to be trained. The training needs analysis must also address the types of cognitive, psychomotor, and attitudinal skills needed.[14] Once the skills have been identified, instructional strategies for training and the type of feedback/debriefing can be considered, including the appropriate levels of fidelity.[15]

These analysis methods often reveal the conditions and **assessment metrics** required to verify that the training objectives have ultimately been met. Thus, the overall educational objectives establish the training expectations while the task, trainee, and training needs analyses specify how those expectations will be met.

Application of System Engineering

The output from the instructional design analysis provides the input to the engineering processes that are used to develop the simulators, software, supporting material and data processing and networking systems that define the capability of the simulator to meet the training requirements. Within the overall engineering community, there are interdisciplinary specialists who make up the Systems Engineering professional community which provides customers with highly responsive, interactive access to the other engineering disciplines as needed to do the engineering of the total system.

Extension of Systems Design and Simulation to Technologies and Environments

Systems design methods that use simulation as a research tool can be applied to other areas of the healthcare system. For example, the focus of the simulation can be on the ability of providers to operate various medical devices.[16] A patient simulator running a medical scenario can provide empirical information on whether instruments or devices are usable and safe.

Simulation has also been used as a means to generate evidenced-based design of healthcare environments such as emergency rooms and ICUs.[17] The architectural and physical design of these environments along with integrated technologies can be evaluated using simulation and human factors methods. Further, simulation can be improved through the development of auxiliary systems. For example, simulation systems can be integrated with medical equipment allowing trainees to become familiar with genuine (real) tools and equipment when interacting within the simulation.

Information/Requirements based on Research by/from Consumers needed by Developers/Engineers

A central issue for system developers concerns the quality of the information available to them to inform their design decisions. Engineering system design methods improve both the efficiency of the developer's workforce and the effectiveness of their product by identifying, acquiring, and using relevant data (Step 1 - Needs Analysis), to 'inform' their design activity (Step 2 - Design Criteria), early in the system development process (Step 3 - Develop an Item), before interest and effort is wasted on risky product introduction (Step 4 - Implementation), to uninformed customers (Step 5, Evaluation), prone to shun the unfamiliar (Step 6 - Transfer) and reluctant to implement new ideas.

To achieve engineering outcomes that meet the needs of the healthcare simulation community, we need to investigate existing methods and adopt or adapt the ability to 1) determine what we actually need, 2) express the need clearly in requirements, 3) work with the engineers to translate those operational requirements into functional requirements, and 4) engage in a proven testing process throughout development and product lifecycle. To accomplish these goals, we need to develop our own capability to collect data and use it to create information for the engineers to incorporate into their design and evaluation activities. Our professional community of healthcare simulation practitioners needs to become "researcher participants", functioning as knowledgeable “data prospectors”.

Everything about our community is changing rapidly. In spite of new technology, the pace at which we recognize opportunities or problems and address them is painstakingly slow. Rather than doing relatively small numbers of studies for which funding and resources can be found, we need to empower the workers in the field to capture their data in retrievable standardized formats. This huge amount of data should be open and available to anyone (especially manufacturers of simulation equipment), hosted by a neutral organization, such as the Society for Simulation in Healthcare (SSH). Considerable good information could be derived from routine instructional events in hundreds of centers using a relatively small number of rigorous evaluation methods with standardized tools for capturing data. The challenge therefore is the means by which the emerging professional community of healthcare simulation practitioners can mature with a research mindset and commit to creating a culture of systemic observation, data gathering and communication with tools that have a minimal impact on their primary responsibility as healthcare trainers. Such an extensive data set would be used to identify successful as well as unsuccessful simulation technologies, and also be available for use in the next round of integrated systems design.

Conclusions

Many simulator systems enjoy commercial success, and have evolved to embrace a wider range of educational requirements. Customer demands and continued discussions of using simulation for licensure and certification within governing bodies and educational committees will inevitably put increased pressure on designers to approach simulator development from an educational objectives perspective, which will require the instructional systems design process.

The systems development models used in other industries provide a framework for healthcare simulation systems, but healthcare is its own complex system of systems. Clearly, additional research is needed on the design methodology for each of the system development steps[18] that are unique to healthcare simulation systems.

As noted earlier, simulation technology developments should be informed through consultation with end users (i.e, needs analysis, even to the point of a National Strategy).[19] Similarly, it is useful for the key stakeholder, often a clinical instructor, to possess some level of understanding of the way the simulator was designed and operates.[20] There is still a need for cross fertilization between the developers and users of simulation.[21] Developers must become more responsive to the needs of the user community,[22] but end users must also be willing to provide the kind of data and information that facilitate the development process, including curriculum integration and standardization of simulation practices.[23] Thus, the healthcare simulation community needs mature researchers (and data collectors) as well as integrated standards for research.

Finally, the path to better simulation systems requires integration of systems design. This necessitates the clinician/educator to have a clear idea of the competencies, not only taught, but more importantly, evaluated by the simulation system. The clinician/educator/user must be involved in each step of the Integrated Systems Design approach to ensure the development of a successful simulator with valid and reliable assessment metrics and competency measures. After all, as customers and consumers of simulation systems, the burden for effective informing is on us, not the developers.

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