Blended Training for Surgeon Education

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ABSTRACT

Complexity in surgery lies at the crossroad between the complexity of the human body and the capabilities of the surgical tools available. While we continue to improve our understanding of the body, we are also inventing new tools to address and correct issues through surgery. As a result, the complexity of surgery is expanding on two fronts simultaneously. This creates a lifetime learning environment for practitioners and a challenge for the systems which educate, measure, certify, regulate, and privilege surgeons. The models of training in this field are slow to evolve and still rest on a foundation of lecture and hands-on practice which has changed little in 100 years. Surgeons largely believe that real hands-on practice with human tissue – excised organs, cadavers, and live patients – is the most effective form of training. But it is also the most expensive, difficult to facilitate, and least accessible form.

The emergence and maturation of the concept of blended learning in public and military education may prove equally valuable in surgical education and training. Creating a learner-centric environment in which multiple modes of education are encouraged, available, integrated, and accredited can potentially increase the level of competence of new surgeons, maintain competence in practicing surgeons, and provide objective metrics to the public and hospital systems.

This paper defines a framework for blended surgical training using principles developed for the military. This framework includes knowledge and skills-based training in both an individual and a group learning environment which includes distance and e-learning sessions, face-to-face engagements, laboratory events, and operating room experiences as modes of surgical education that are not integrated into a coherent program with defined metrics. The goal of the framework is to apply blended learning principles to the surgical education and training community, with reference to prior activities in public and military education.

Keywords: blended learning, learning science, surgical training, medical education

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NATURE OF SURGICAL EDUCATION

Developing the ability to perform surgical procedures requires mastering complexity in multiple dimensions. It calls for cognitive knowledge, psychomotor skills, and team management techniques. Mature attending surgeons must be competent in all of these to lead a surgical team through a procedure in which a patient's health and life are at risk. Accomplishing all of this has led to extensively long educational programs which typically include a four year bachelor degree, a four year medical degree, a three to five year residency, and perhaps a two year fellowship. But in many countries, safety regulations have limited the number of hours that a resident or fellow can learn and practice during this process (Funke, 2013). At the same time, the explosion of medical tools and technologies has led to ever increasing numbers of available procedures and the specialized knowledge that accompanies these. Acquiring more knowledge and skills by increasing the number of practice hours is not possible, so one alternative is to improve the methods of education, hopefully increasing the speed at which mastery can be attained through more efficient educational methods.

Beyond the formal educational programs, practicing surgeons are also constantly acquiring new skills through continuing medical education (CME) courses. These provide knowledge, skills, and team management for a new procedure, tool, or technique in a one or two day event. The degree to which this material is mastered is based, not just on the quality of the instructor and the intelligence of the student, but also on the instructional methods that are applied and the tools which are used to transfer knowledge and skills. Instructors for these courses typically prepare traditional slide presentations, videos of procedures and tools, and hands-on laboratory sessions with tools and tissue. Assessment of performance and skill acquisition is usually based on subjective instructor observation and quantitative scores on exams. But these courses typically lack an objective metric for the acquisition of psychomotor or team management skills. Educators search for additional tools and methods that can provide accurate assessments of performance in these compressed events.

Medical education from CME to under graduate medical school has always attempted to blend books, hands-on labs, apprenticeships, and research (Cooke, 2010). This model has been created, but its implementation is different at every institution based on faculty abilities, facilities available, patient presentation, scheduling, and other factors. This results in a wide variation of effectiveness and the emergence of a rumor-based reputation of the quality of each program. Nissen (2015) has recently published his view that CME in particular is not effective at improving surgeon performance or patient outcomes. He maintains that the CME system of education as a whole needs to be reformed, a major criticism of the current practice.

BLENDED LEARNING

While medical and surgical educators search for effective teaching methods and tools, the public schools have been actively developing concepts labeled as "blended learning" (Bonk, 2006; Horn and Straker, 2015). In its current form, this focuses on the integration of in-class, lecture-based instruction with electronic, online, independent educational materials. Horn and Straker (2015) have explicitly identified four dominant models of blended learning that are in use in America's classrooms. These include – the rotation model, flex model, a la carte model, and enriched virtual model. Each of these represents a different sequencing or emphasis of learning via teacher-led instruction, collaborative activities, and online instruction. Given the estimated $60 billion investment in computers for classrooms (Christensen, 2011) the emphasis has been on how to add value equivalent to this enormous investment in basic technology.

Popular definitions of blended learning focus on this public school environment.

> "Blended learning is a formal education program in which a student learns at least in part through delivery of content and instruction via digital and online media with some element of student control over time, place, path, or pace. While still attending a 'brick-and-mortar' school structure, face-to-face classroom methods are combined with computer-mediated activities." (Horn and Straker, 2015)

This is certainly one important environment. But the structure and limitations of the K-12 classroom are not necessarily appropriate for other environments. Throughout these two books there is an emphasis on control of immature students and assessment via tests which indicate whether the student should progress. But there is little consideration for adult learning in which assessment can take more interactive and dynamic forms, such as demonstrated performance of skills. McCafferty and Desaulniers (2004), Fautua et al (2014), and Schatz et al (2015) have all explored what blended learning can contribute to military training programs. Their work and lessons learned appear to be much more similar to adult medical and surgical training than the K-12 educational texts on blended learning.

But a more appropriate and useful definition is something similar to that quoted from Michael Orey in McCafferty (2004):

> "Blended learning is the ability to choose among all available facilities, technology, media, and materials matching those that apply to my prior knowledge and style of learning as I deem appropriate to achieve instructional goals."

This definition is much more encompassing of all learning tools and methods available. It also seems to capture an active role on the part of the student, rather than treating the student as a passive agent to be acted upon by the teaching system. Peder Jacobsen cites a US Department of Labor study which estimates that 70% or more of all learning occurs on the job, not in a structured classroom or educational environment. This means that traditional educators and formal education materials are only able to impact 30% of the learning experience. This calls for both effective methods for impacting that limited volume of experience and a search for methods which can become part of the majority 70% that is happening in other environments (Saltzman, 2010).

Military training organizations have adopted the terms "Live, Virtual, and Constructive" to refer to different modes, objectives, and methods of simulation-based training. These terms came into popular use in the late 1990's to describe the literal situation that existed at that time. Training events could be defined as purely Live, or Virtual, or Constructive, lacking the technology and experience to integrate any two of these together. Today the terms have merged into the "LVC" acronym which indicates that we have arrived at a state of blended training in which all three are generally included in any simulation-based training event of significant size. This evolution has relied on improvements in computer and networking technology, but also on the expertise of scientists and engineers who have developed an understanding of how to bring these together. Accomplishing this in an educationally effective manner has been a different and slower process to emerge. The blending of technologies together may have been accomplished without an understanding of how the resulting product would be used, so lacking capabilities that would be essential for effective learning events. Similar challenges exist when attempting to blend simulation into medical education (Gardner, 2015). As a result, educational designers are often faced with a simulation federation which is not well designed to support the needs of the training and education mission. Fautua et al (2014) offered ten recommendations, some of which can be applied to engineering the technology in support of blended learning objectives (Table 1).

Table 1. Fautua's Recommendations for Effective Blended Learning

1. Provide the reason why for goal-oriented adult learners.
2. Gain commitment to the training by trainees and their leaders.
3. Create content which can be reapplied to sustainment training.
4. Focus on the staff being trained, not the canned event.
5. Embed diagnostics which can guide other learning modes.
6. Schedule and plan for remediation.
7. Train the trainers to apply blended concepts.
8. Collect feedback throughout the blend.
9. Emphasize human-system integration.
10. Shift the culture of trainees, trainers, and leaders toward blended approaches.

Each of these represents a very valuable lesson for other subject domains, such as medicine and surgery, and were applied in the development of a blended training framework for surgeons, as presented in this paper. This leads to the need for a larger definition for the term, something more akin to:

> "Learning in the 21st century, especially with adults, requires leveraging all of the information delivery, communication, data collection, and assessment tools that are available. Blended learning may be a useful term to discuss, design, and evaluate learning methods that are very different from those of previous generations, even to the extent of eliminating face-to-face sessions and expert instructors. Perhaps the greatest value in the term 'blended learning' is not in defining it, but in allowing it to undefine the historical approach to education." (Original derivation by the authors for surgical course design.)

SURGICAL BLENDED LEARNING

Just as previous works have applied and expanded blended learning concepts to military education and training, this paper extends those ideas to the field of surgical education. Organizations which offer adult, surgical, continuing education wrestle with many of the same challenges and opportunities as the K-12 and military education systems. But, time is a driving concern when trying to separate practicing surgeons from their daily duties with patients, staff, and hospital administration. Little time is available and each hour that is allocated must provide a return greater than the good which could have been performed in the direct delivery of care.

Adult surgical training programs, often referred to as Continuing Medical Education (CME), generally focus on the hands-on psychomotor skills acquisition through the use of new tools, new techniques, and realistic tissue models. These are excellent learning and practice environments which can be produced only in specialized facilities for a limited number of participants. Blending this core event with other technology-enabled modes of education could potentially deliver knowledge and skills more smoothly, while also improving the learning density of the high-end core event.

Figure 1 illustrates two of the most common pathways for CME in surgery. The traditional path (T) begins when students physically arrive at the training location and assemble as a group in front of the faculty member. This very familiar path is dominated by lecture and typically incorporates photos and vivid videos of surgical performance. It is typified by a one-way flow of information and knowledge. The second step in this path incorporates hands-on laboratory practice with tissue models. The initial focus is on knowledge, which then flows into applying that knowledge to develop specific skills. Students are expected to apply both of these in their surgical practice when leaving the course.

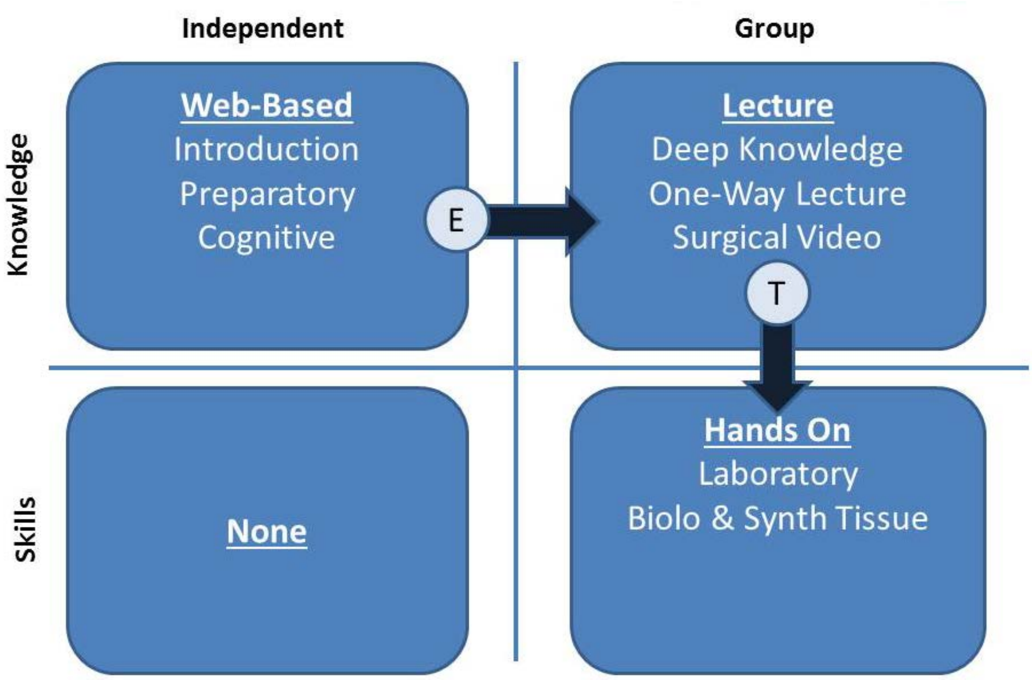

Figure 1. Traditional (T) and Extended (E) Surgical Learning Path for CME

Courses of this type are typically offered in a condensed single or multi-day format. Surgeon-students in most countries can afford to allocate only a few days to attend such a course and are eager to carry what they learn back to their practice.

The second extended (E) pathway enables learners to familiarize themselves with knowledge materials prior to physical assembly at the course. This occurs through online, web-based, internet enabled materials and could rightly be seen as equivalent to the traditional definition of blended learning bridging the internet and the classroom. This mode is expected to either reduce the amount of group time required for the lecture phase of the physical class, or seen as an opportunity to reinforce information by presenting it multiple times in different formats to improve retention. Currently, few or no courses prescribe an independent curriculum of skills exercises prior to physical attendance at a course, though there are opportunities to add this modality.

Experience with hundreds of surgical CME courses indicates that there remains a great deal of opportunity to further extend and enhance the learning pathways which can be applied effectively. Blending methods for surgeons who must learn knowledge, skills, and teamwork calls for a broader view of the blended term and a less linear and standardized version of training for the surgeons. The model shown in Figure 2 illustrates the opportunities that exist with the tools and technologies that are available and experience with directing students through an enriched form of education and training.

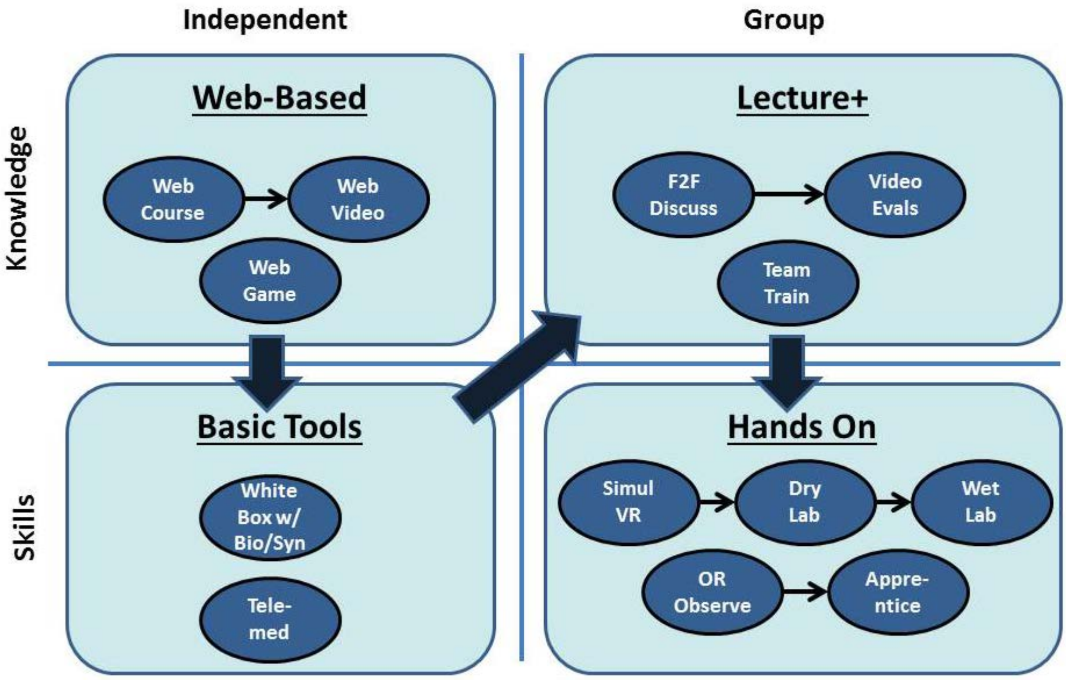

Figure 2. Enriched Blended Learning Environment for Surgical CME

Within this model the two dominant existing learning pathways can still be seen. But they have been enriched internally and extended externally to take advantage of tools and technologies that currently exist, but which are seldom integrated into the learning experience.

Independent-Knowledge

This model begins with independent knowledge acquisition in which each student accesses introductory and case-based materials on their own, typically prior to group events. There are hundreds of online, web-based, case-based courses available today. One huge library of these which focuses on surgical videos can be found at the European WebSurg.com site maintained by IRCAD (Institut de Recherche contre les Cancers de l'Appareil Digestif) in Strasbourg, France. Dozens of training centers, medical device companies, and universities maintain similar, but smaller, online libraries which can be blended into a specific, custom surgical curriculum. These are attractive resources because many medical educators believe that e-learning leads to faster knowledge acquisition and better retention rates (Ruiz, 2006).

More recently, there have been a few game-based learning tools which focus on surgery. These provide a more interactive and dynamic experience which can respond to the learner’s actions and provide corrective guidance.

One such tool is the Fundamentals of Robotic Surgery Team Trainer (www.trainrobotic.com) which was designed to guide a surgeon through TeamSTEPPS procedures in a robotic operating room environment.

Independent-Skills

The independent acquisition of basic skills prior to group instruction is not typically part of an instructional curriculum. However, using a number of existing, low cost "box trainers" and inexpensive disposable instruments a surgical student can practice maneuvers which are demonstrated in online course materials. Through centuries of surgical education, a model for the substitution of various grocery meats, excised organs, and animals has evolved to replace practice on live humans. These materials are recognized as acceptable learning environments and many of them are readily available to any learner. More recently, this model has been augmented with an array of synthetic materials which are available from vendors or can be manufactured from silicon compounds.

Telemedicine sessions can also be conducted in which an instructor remotely views the performance of the student and provides customized feedback. Cellphones and laptops are all equipped with the necessary hardware and software to enable this remote, but individualized, instruction. However, this has not yet been integrated into surgical education programs. This mode has the potential to make a significant contribution to student skills prior to group assembly, just as online material is used to build a base level of knowledge prior to a traditional course.

Group-Knowledge

Traditional courses have been very heavy with the dissemination of knowledge materials in a group setting via lecture and videos of actual surgeries. These remain an important part of a blended curriculum because they allow synchronous discussions between students and instructors. But these may also be supplemented with team training role play and table top exercises.

Group learning has typically assumed that all of the participants are physically assembled together for the event. But with the advent of online virtual worlds, it is also possible for group interactions to be facilitated via computer networks. F2F group training may be supplemented with virtual worlds, or the team training may occur prior to the physical meeting, as is accomplished with tools like 3DiTeams (http://www.virtualheroes.com/portfolio/Medical/3DiTeams).

Group-Skills

Surgical training programs are currently most heavily focused on a group setting for skills development. This mode is primarily accomplished with wet and dry lab exercises (biologic and synthetic materials). But it could also include the use of new virtual reality simulators, OR observation, and apprenticeships with an experienced surgeon.

Blending the curriculum between simulators and wet/dry labs has proven to be more difficult than it would first appear. Surgical simulators are faced with computational limitations on representing the behavior of soft tissue and blood flow. These soft features are unique to the human body and have not been previously addressed by either the military simulation or the video game visualization communities. Those domains have made significant improvements in the visualization and physical behaviors of hard, rigid objects like vehicles, terrain, and weapons. But they have done little in the area of tissue flexibility. Even soft objects like clothing and hair have been modeled as rigid objects, rather than tackling the soft fluid behavior problems. Given this situation, surgical simulators typically focus on exercises which develop specific motor skills with simple puzzle environments – e.g. pegs, rings, rails, and simple sponges. This has led to exercises which develop basic, beginner-level skills, but which do not represent the realistic human tissue and blood flow that are necessary for models of real procedures. Funke et al (2013) and other authors maintain that simulators are valuable for younger students, but not for more experienced practitioners who need real patients, partly for this reason. This means that the simulators offer an experience that is similar to simple box trainers, but with more accurate and automated metrics collection. Blending these into a curriculum is difficult to justify when evaluated via a cost/benefits analysis. VR simulators are just beginning to include soft tissue models of procedures with bleeding. As these improve, there will be a unique place for them in many curricula.

OR observation and apprenticeship are a very attractive and popular part of a surgical course. Learning surgeons are eager to see an experienced instructor performing real procedures with human patients and explaining the challenges and rational for each step. This level of realism is difficult to reproduce in wet/dry labs or simulators, so represents a unique learning opportunity which includes real time discussions with the instructor.

Using these four categories as the framework, blending learning content across all available modes yields a surgical education framework as shown in Table 2.

Table 2: Blended Learning Framework with Specific Surgical Content

Independent Knowledge	
Web Course	Introductory knowledge about diagnosis, medical indications, instruments, OR resources, approach to anatomy, legal regulations, and costs. Explain the rich environment and history in which the instrument or procedure exists. Create a common knowledgebase before group events.
Web Video	Introduce the common use of the instrument or the procedure. Present multiple variations and complications that can arise. Organize complications into categories with a shared set of solutions.
Web Game	Create an interactive case-based problem for diagnosis, decision making, and an appreciation for the complexity of the environment and the procedure.
Independent Skills	
White Box	Prescribe skills exercises which can be accomplished independently with accessible and affordable devices and tissue. Encourage rehearsal of common approaches and skills. Demonstrate self-guided education pathways for use in training residents.
Telemedicine	One-on-one remote evaluation of white box skills. Personalized direction on improvement and collection of pre-course metrics for improvement.
Group Knowledge	
F2F Discussion	Prior independent activities transform this mode from one-way lecture to two-way discussion. Less focus on basic knowledge and more attention to subtle details and potential solution approaches.
Video Evaluation	Evaluation of video cases as an educated cohort of professionals, rather than one-way explanation of basic features of the case. Highlight situations which will be presented in later group skills sessions.
Team Training	Role playing for basic procedures and extended complications. Table top exercises on resource management and interactions with other departments.
Group Skills	
Simulation VR	Hands-on experience with skills exercises and automated metrics collection, contributing to learning curve improvements. Pre-qualification for use of real instruments and tissue.
Dry Lab	Focus on capabilities and features of instruments, approaches to tissue, planned intervention on patient.
Wet lab	Application of instruments and approach to biological tissue (animal and cadaveric). Focus on response of real tissue to previously learned use of instruments. Environment for some complications and unexpected responses.
OR Observation	Observation of real environment with experienced instructor. Interactive discussion on strategy, expectation, and process. Opportunity for complication and resolution.
Apprenticeship	Partial participation in real environment. Opportunity to perform as part of an experienced team. Open to guidance and criticism by instructor surgeon.

LEARNING METRICS

The technologies that make rich and effective blended learning possible also offer the power of accurate and automated metric collection and computation. Schatz et al (2015) emphasized that blended curricula and systems should create a learner-centric model of education which is data driven and ubiquitously accessible. Technology and blending techniques can transform the industrial model of uniform education into something that is more customized with more objective metrics of performance.

When implementing blended learning programs at IBM, Lewis and Orton (in Bonk and Graham, 2006) reported that evidence of effective programs was determined by (a) student reactions to the experience, (b) measured learning that occurred, (c) evidence of transfer to practice, (d) measurable business impact, and (e) a positive and significant return on investment (ROI).

The metrics of greatest interest in surgical training are almost identical to these. Student reaction to the experience is important for repeatability of the program when surgeons have multiple options for learning the material, as opposed to mandatory programs where the learner cannot select out. Formative and summative assessments are typically part of the educational program to provide feedback to the hospitals or surgical boards that support or prescribe the training. Some of these metrics for a blended program are described in more detail below. Evidence of transfer to practice has been a universally difficult metric to collect. Most courses send surgeons a survey between one and two months post-course asking for their feedback on how the training has impacted their practice of medicine. These are problematic because most surveys are not completed and returned (anecdotal rates are 5-10%), and those that are represent self-reported application without objective data to support the claims. Physician practices and hospital departments do have some ability to measure the business impact of courses which enable new procedures or the use of new devices. These can be measured by the number of patients who have been treated using the new skills and knowledge. Though objectively measurable, this information is typically considered business proprietary and is not shared with the external organizations that provide the training. The medical community would expand the scope of this metric to include “improved patient outcomes” as a measurable business impact which is important to society. Using this same data, practices and hospitals are able to calculate the ROI for new procedures and devices, and this information remains private within the business unit as well. However, business impact and ROI can be inferred when the same organization repeatedly sends surgeons to a program.

Instructional designers are generally most interested in metrics which can be extracted during the educational process as evidence that learning is occurring, as opposed to the other meta-categories given by Lewis and Orton. Some typical metrics which can be collected are shown in Table 3. One purpose and advantage of blended learning is that performance can be improved through multiple learning modalities and learning metrics can extend across multiple modalities to provide a better measure of performance than when confined to a single mode. To illustrate this, the table is structured to show metrics which can be shared in common within a category.

Table 3: Blended Learning Metrics

Independent Knowledge	
Web Course Web Video Web Game	Number of correct/incorrect responses to test questions interspersed within web pages, video, and game vignettes. Efficiency through a game’s learning path and selection of correct/incorrect branches in the course, video, or game.
Independent Skills	
White Box Telemedicine	Collection or observation of materials showing incisions, suturing, knots, etc. One-on-one remote evaluation of white box technique.
Group Knowledge	
F2F Discussion Video Evaluation Team Training	Interactive demonstration of knowledge and understanding. Accuracy of role playing and efficiency of resource usage.
Group Skills	
Simulation VR Dry Lab Wet lab OR Observation Apprenticeship	Digital metrics for efficient hand movement, errors, instrument collisions, blood loss, etc. Human observation of same metrics in labs and apprenticeship. Collection of synthetic tissue materials showing incisions, suturing, knots, etc. Damage to biologic and synthetic tissue, blood loss. Discussions with surgeon to demonstrate understanding. Observed and guided technique in apprenticeship.

CONCLUSION

Surgeon leaders like Richard Satava (2009) and Ajit Sachdeva et al (2016) have been promoting the addition of simulation devices to surgical training for a decade or more, along with the integration or blending of this tool with existing modes of training. These efforts have had a noticeable impact on surgical training in specific areas (Gardner et al, 2015). Details on how to implement the integration of simulators have been proposed by various training centers around the country that are associated with the American College of Surgeons.

Most students and instructors have experienced courses in which the age and relevance of the material are in need of revision. Over time content and presentation standards change. Outdated material threatens to provide both incorrect educational materials and an experience that is viewed with disdain because of its visible age. Blending multiple modes and devices into a single learning experience is a challenging endeavor. But, once accomplished, the difficult work is not finished. There remains the challenge of preparing an instructor to lead students through the blended curriculum, installing and training the technical staff that will build and maintain the electronic devices and information resources which enable the course, planning for the sustainability of the program over time in terms of cost and staffing, and planning for technology refresh as the devices and materials age. Kern and Hughes (2009) and McCaffery and Desaulniers (2004) both emphasize the need to keep pace with changes that occur in the teaching and simulation tools and in the knowledge and skills that are being presented. Creating complex blended courses brings with it the added effort and cost of updating the materials across all modes in order to maintain the relevance of the course. Organizations seeking to leverage the immediate advantages of multi-mode blended learning should be aware of the long-term commitment to investing more money and time to keep the material relevant.

Creating a blended surgeon course is not just a project which can be accomplished in the near term and used indefinitely. A course which touches on all of the modes shown in the framework presented here may be effective and impressive for a period of a few years, but will eventually need a substantial investment of time, money, and expertise to maintain its level of educational effectiveness.

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