Chapter 9
Didactic Education and Training for Improved Intraoperative Performance: e-Learning Comes of Age

E-learning

E-learning comprises all forms of electronically supported learning and teaching which are aimed at imparting or facilitating the construction of knowledge. E-learning is perceived by many as made up of the computer and network-enabled transferor of knowledge. Applications that facilitate this process include web-based learning, computer-based learning, virtual classrooms, and digital collaboration. The vast and extensive development of the Internet has facilitated what many individuals perceive as the engine of e-learning. However, e-learning has been available long before the widespread availability of the Internet. The Open University (OU) in the United Kingdom was one of the developments that came out of Harold Wilson's government which was elected in 1967. The OU was the world's first successful distance teaching university and was founded on the belief that communications technology could bring high-quality degree-level learning to people who had not had the opportunity to attend campus universities. Prof Walter Perry, who had been a professor of Pharmacology at Edinburgh and a member of the Medical Research Council staff, was appointed as the first vice chancellor of the OU (or as it was then known "University of the Air"). Perry was convinced to become involved because he believed that the standard of teaching at conventional universities was pretty deplorable. One of its initial ambitions was to use the media and other devices to deliver course materials that would allow students to learn by themselves. This, he believed would inevitably effect – for good – the standard of teaching at conventional universities. The university expanded during the 1980s and harnessed new technologies for the delivery of course material. These new methods included the use of computers and multimedia mix. Courses were delivered in written form, via radio programs and some television programs. In the mid-1980s, there was a rapid expansion in the growth and use of personal computers which enhanced the possibilities for the delivery of OU courses. Students, mostly adults, embraced learning on personal computers, CD-ROM, and web-based media with enthusiasm. By the mid-1990s, the university began a massive exploitation of the Internet which made the OU the world's leading e-university.

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E-learning Benefits

Early e-learning systems and computer-based learning packages often attempted to replicate autocratic teaching styles whereby the role of the learning system was assumed to be simply the transfer of knowledge. However, pioneers such as Graziadei (1997) realized that e-learning could be much more than this. The potential benefits of an e-learning system are enormous and include:

- *Increased access*: Via whatever type of electronic technology (but usually the Internet), students can access academics from around the world, thus acquiring knowledge that is not constrained by physical distance, political ideology, or economic boundaries. In surgery, this gives trainees access to information and courses in centers of excellence. What is true for the student is also true for the academic institution. This means that they can deliver large amounts of their academic content to anywhere in the world.
- *Convenience of access*: The development of e-learning means that course content is available at any time of the day to anywhere in the world and is not bound by the size of a lecture theater. While there are many constraints on operating room access, the same rules pretty much hold true as well, i.e., only so many observes can be accommodated in an OR.
- *Convenience of use*: Users of e-learning can access the materials from a location that suits them whether this is their home, the hospital library, or indeed their own desk. The reverse is also true where users can access the same materials from a variety of locations. The usual constraint is access to the Internet.
- *Distributed training*: As we shall see later in this chapter, knowledge and skill are optimally acquired when spread out over a period of time rather than massed into an intense course. E-learning facilitates this process.
- *Facilitates the development of computer skills*: Modern medicine cannot be practiced effectively and efficiently in the absence of good computer skills. E-learning enforces varied and continued practice of the these skills.

The Traditional Lecture

A lecture is an oral presentation intended to present or convey critical information or teach an audience about a particular subject. Although the use of lectures is much criticized as a pedagogical method, (most) universities have not yet found a practical alternative teaching method to deliver the vast majority of their courses. Lectures delivered by a talented speaker can be highly stimulating. They have also survived in academia for some considerable period of time probably because they are quick, flexible, cheap, and efficient at introducing large numbers of students to a particular field of study. The practice in the medieval university was for the instructor to read from an original source to a class of students who took notes on the lecture. The reading from original sources evolved eventually into reading from lecture notes. Throughout much of history, the spread of knowledge through handwritten lecture notes was an essential element of academic life. Unfortunately, some lecturers today are accustomed to simply reading their own notes from the lectern much as 500 years ago. The use of multimedia presentation software such as Microsoft PowerPoint has changed the form of the lecture which can now include video presentations, animated graphics and web-based material. Most lectures continue to be presented verbally and augmented with PowerPoint bullet points.

Traditional e-Learning Packages

When virtual reality simulation was first thought of in surgery, it was widely perceived to be a panacea for many of the ills of surgical training. It has taken almost two decades for the surgical community to realize that virtual reality simulation and indeed simulation per se is simply a tool for the efficient and effective delivery for part of the curriculum. Unfortunately, e-learning suffers from the same misperception. For some it is perceived as a new and trendy way to deliver educational material; for others, it is simply a way of delivering a lecture to more people in more diverse locations. E-learning may be all of these things, but more importantly, it is potentially a very powerful and effective tool for the efficient and effective delivery of the curriculum. There seems to be considerable effort put into the content of e-learning packages, i.e., what it looks like, eye catchy material such as grand rounds delivered by a famous surgeon in a famous hospital half-way around the world. Content is only part of what makes a good e-learning package. Of equal importance is how the content is configured, delivered, and assessed so as to optimize learning in an efficient and effective manner. To achieve this end requires an explicit understanding of where and how it can be used to gain the greatest effect. Human beings are not passive recipient vessels for information no matter how enthusiastic or committed they are to the learning process. Likewise, human beings are not empty vessels which we fill full of skills in our skills laboratories and operating rooms. As shown in Chaps 3 and 4, human beings are active information processors. Although they process vast quantities of information from their immediate environment, this information is filtered from the outset. Initially, by a perceptual system that filters and organizes the information that is sensed and then by the working memory system that decides whether or not to attend to the information. The information that does reach short-term memory is then organized and "chunked" before storage in long-term memory. The information that is chunked and stored can be of multiple sensory modalities and this is particularly likely to be the case in learning material related to clinical surgery. For example, trainees are likely to have to learn information by listening to instructions (auditory information) about a surgical procedure that they are watching (visual information) being performed or that they themselves are actually performing (kinesthetic information).

E-learning Optimized

E-learning is naturally suited for the delivery of multisensory information such as material associated with learning to perform surgery. It can provide a flexible learning environment that can be used as an adjunct to face-to-face teaching, skills laboratory training, and clinical surgery training for both novice and very experienced operators. E-learning offers particularly exciting opportunities for augmenting the learning process in surgery and procedural medicine. For example, in a well-delivered traditional lecture, the academic has very few ways of knowing how effectively they have imparted the information that they are trying to communicate. Furthermore, it would be unrealistic to expect that all of the audience would be learning at the same pace, but the traditional lecture is delivered in the standard 40–50 min time period to the individuals sitting in the same room. The hope is that by the time of the exam, everyone is at a sufficient standard to at least pass the course. If the material is delivered on an e-platform, the progress of each individual can be tracked with a formative assessment process. This means that individuals who learn at a slower pace can have their education supplemented automatically or they can be flagged for direct academic intervention.

The education and training of a surgeon is all about one thing, i.e., preparing trainee surgeons to take care of patients, nothing more and nothing less. As seen in Chap 8 there are multiple aspects to this in terms of professional behavior, interpersonal behavior, etc. However, as identified in the CanMeds, at the core of this process is the assumption that the surgeon is a safe operator. Another core assumption is that what the surgeon is taught will prepare them for operating and taking care of patients. In other words, it is hoped that knowledge and skills acquired in the classroom and skills laboratory will generalize to the operating room specifically and to patient care generally.

Transfer of Training

In Chap 4 we discussed the different types of factors that affect the efficiency of psychomotor skill acquisition. These factors or, more accurately, these contingencies should be optimally configured for efficient learning. We proposed that virtual reality simulation affords an ideal opportunity to marshal and to configure these variables for optimal effect. By and large, the variables which are important for learning on a virtual reality or physical model simulator are also important in an e-learning package. The end goal of the process is the same, i.e., a proficient surgeon. Generalization is one of the most powerful learning processes where knowledge or skills acquired in one context have positive effects on another similar situation. It is the application of a skill learned in one situation to a different but similar context. For example, in Chap 6 we described the process of training on the MIST VR system until a predefined level of technical skills proficiency was reached. When surgical trainees had acquired this objectively defined performance criterion level, they were then allowed to perform the surgical procedure on the real patient. Although the MIST VR tasks looked nothing like the anatomy of a gallbladder, the assumption was that skills acquired on MIST VR would generalize to the LC. The reasons were: (1) MIST VR trained the appropriate psychomotor coordination of laparoscopic instruments; trainees were required to hold a target object in (virtual) three-dimensional space with one hand while applying electrocautery with an instrument in the other hand and pressing a foot-pedal when the electrocautery instrument was touching the target object. (2) MIST VR trained the surgical trainee what to do, but more importantly what not to do; to successfully complete the task, the target object had to be held in a stable position within a predefined virtual space and then small cubes on the surface of the target object had to be burned off with the electrocautery instrument. Electrocautery could only be applied when the target object was within the predefined space; otherwise, an error was scored; if electrocautery was used when the instrument was burning non-target objects, an error was scored; an error was also scored if electrocautery was used when the instrument was not touching any object. This may seem somewhat abstracted from performing a LC; however, on closer scrutiny, it is not. This task taught appropriate use of surgical instruments, choreographed use of surgical instruments to complete the task, practice in hand-eye-foot coordination, and trainees were also taught how to perform the task with a minimum of errors and using electrocautery efficiently. They were also given feedback on their performance with formative feedback proximate to errors and summative feedback when they had completed the task. The results of this training speak for themselves; surgeons trained on MIST VR to a level of proficiency made six times fewer objectively assessed intraoperative errors when operating *in vivo* on real patients than subjects traditionally trained (Seymour et al. 2002).

The lesson to be learned from this example is that a great deal of learning can take place on appropriate training tasks that have good feedback on performance and are configured in a way that they emulate the crucial aspects of the real world task. Training on these tasks generalizes to real world tasks and there is good evidence to support this conclusion. The general rule is that the closer the simulation or the emulation is to the real world task the greater the amount of skills that will be transferred. One would expect even greater transfer of skills from a high fidelity simulator such as VIST in comparison to MIST VR. It should also be noted that the higher the risk of adverse events from the procedure to the patient, the higher the fidelity and more accurate the simulation should be. We must emphasize here that we are not simply referring here to the fact that a simulator "looks" like the real procedure. Rather, we would expect that the simulators for training high-risk procedures look, feel, and behave like operating on a real patient (or close as possible). It will never be possible to devise a VR simulation that looks, feels, and behaves EXACTLY like the real patient but a full physics simulation environment such as VIST will provide a very realistic approximation.

The function of e-learning should be the same as training on a simulation model, i.e., support for delivery of the curriculum. E-learning and simulations are not something apart from the curriculum but should be viewed as tools for the efficient and effective delivery of the curriculum. Virtual or physical model simulations afford the opportunity for hands-on interactive training, which is a particularly powerful way for the acquisition of procedural skills. However, e-learning can also be a powerful tool, if used in the correct way.

One of the goals of e-learning and simulation training is to have the trainee as well prepared as possible for their training in the operating room. Although minimally invasive surgery has been blamed for many of the problems facing surgeons in training, one of the major positive changes that it brought about is that it forced medical educators to systematically think about the entire training process. Traditionally, the operative surgical training started and ended in the operating room. With the advent of MIS, it very quickly became clear that the operating room was an inappropriate environment to acquire basic skills for this type of surgery. The surgical community realized that before trainees could commence their clinical training in the operating room, they had to at least have the basic psychomotor skills with which to operate. This meant that the early part of MIS skills training took place in the skills laboratory rather than the operating room. Compounding these training difficulties was the reduction in work hours in the United States and Europe. The surgical community looked for new training devices and strategies with little systematic understanding of why particular strategies or devices were effective, e.g., more training is better! This was despite the fact that there was more than 100 years of research data and knowledge that was directly applicable to this problem. In our review of this literature in Chap 4 we outlined the strategy that can be implemented in a curriculum via a simulation device to overcome these problems. Although surgery developed training solutions for the skill acquisition problems posed by MIS, these solutions were not developed from first principles, but rather, intuition. Furthermore, devices such as MIST VR which were developed and did adhere to sound behavioral principles for training and learning were frequently dismissed as not looking like they would do the job they were designed for.

Elements of Transfer of Training from e-Learning

Verified Pre-learning

Virtual reality simulation provides a very good interim opportunity for hands-on skill acquisition. However, technical skills for surgery are not practiced in a vacuum. They need to be learned and practiced in the context. One of the problems currently faced by skills laboratories around the world is that trainees turn up for their 1 or 2 days skills training course with considerably variable preparation. Some candidates turn up very well prepared and have done the appropriate reading on the disease process or the organ system on which they are to be taught to operate on; they know the anatomy and physiology, surgical instruments to be used, and possibly some of the operative techniques. Other candidates turn up, with little or no preparation at all, and consider it fortunate that they turned up at all!. Unfortunately, the trainers organizing this type of skills laboratory are tied to the level of the candidate who turns up with no preparation. E-learning allows for the situation to be completely avoided. At the Royal College of Surgeons in Ireland, surgical trainees pay an annual fee that runs into thousands of Euros for access to courses in the skills laboratory. The skills laboratory has courses scheduled for the entire year. This means that training time in the lab must be used effectively. The problem of the ill-prepared trainee could be dealt with by scheduling study and assessment of online material prior to attending the skills laboratory. Candidates wishing to train in the skills laboratory would not only have to study the online material, they would also have to pass a predefined level, before even applying for a training slot. This would mean that candidates turning up for training would be well prepared. This process could also help to optimize the training they do receive in the skills laboratory. For example, all candidates attending training would have passed the online didactic component for the course. However, across members of the class, a consistent aspect of the didactic material, e.g., anatomy and physiology, laboratory tests, operative procedure etc., may have been poorly understood as indicated by the number in the class who got that part of the assessment wrong. In light of this information, the course leaders could investigate why it was that the trainees found this aspect of the material difficult to understand and cover the material in more detail in the classroom. The advantage of this approach is that it guarantees a sufficient level of knowledge to ensure that skills laboratory training progresses in a timely fashion; it highlights potential weaknesses in a candidate's knowledge that can be rectified, and it ensures the course faculty that the trainees are motivated, i.e., they made the effort to undertake study and assessment of the online material as it related to the skills course. This is considerably more information than is currently available to course faculty. Furthermore, it puts the onus of knowledge acquisition clearly on the trainee. The faculty and the training body have provided sufficient and appropriate learning material to prepare for the course and the trainee is not allowed to attend until they have passed the online didactic material.

Pre-learning: Declarative Memory

To get the most out of training on a simulator, the trainee should know background information on the task/procedure they are learning, i.e., context. They should also know when, where, how to do it, and what with. The trainee can either learn this information in the skills lab just prior to participating in hands-on training on a simulation model or they can acquire this information before they attend for training. All of this information can be delivered prior to training.

When a surgeon performs an operative procedure, the skills that they apply are based on information that they have retrieved from their long-term memory, which

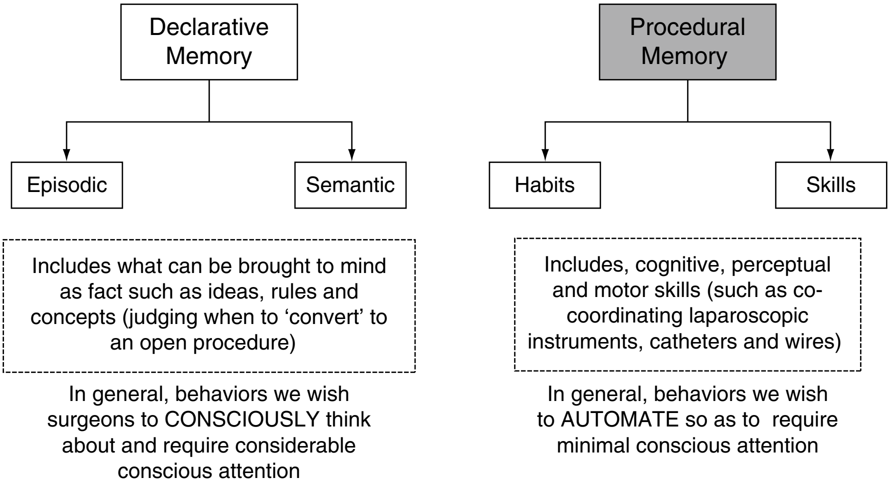

Fig. 9.1 Different types of attributes of declarative and procedural long-term memories

they have learned from didactic teaching, reading, and probably skills practice on simulation models. They may also have acquired information from observing others or from what others have told them. This information, retrieved from long-term memory, is one of two types of human long-term memory, i.e., declarative memory and non-declarative or procedural memory. These two types of memories are crucial for skilled performance. Declarative memory refers to information which can be consciously recalled, such as facts and events (Keane and Eysenck 2000). Non-declarative or procedural memory refers to unconscious memories such as those pertaining to skills and habits like riding a bicycle or driving a car. Figure 9.1 shows a diagrammatic representation of the different types of long-term memories and their attributes.

Declarative memory can be subdivided into two different types; semantic memories contain factual knowledge that is independent of the individual's personal experience. Types of semantic information in surgery would include signs and symptoms, anatomy and physiology, laboratory test norms, etc. Episodic memories are those that are idiosyncratic and personal to the individual experience. Semantic memories may consist of information remembered from a particular course attended by the individual and the information on a particular disease system. However, episodic memories relating to the same course may contain information on who they attended a course with, whether they enjoyed the course or not, what they did badly on the course, or on what they excelled. Episodic memory information concerns fairly sharply circumscribed concepts. Furthermore, episodic memory is believed to be the system that supports and underpins semantic memory (Tulving and Thomson 1973). Episodic memory appears to apply meaning to information and situations and appears to make information easier to recall. Semantic information can be learned but it seems to be less "easily" learned than episodic information. One of the tactics in optimizing memorization of information is to facilitate the learner applying episodic "tags" to the information. This means that the information is more "meaningful" and hence easier remembered.

E-learning can facilitate the application of these strategies to enhance the storage and to facilitate the retrieval of information necessary for the learning and practice of surgical skills. For example, information on gallstones and cholecystectomy could be linked to a famous British Prime minister, Anthony Eden. A medical mishap would change the course of Eden's life forever. During an operation in 1953 to remove gallstones, Eden's bile duct was damaged, making him susceptible to recurrent infections, biliary obstruction, and liver failure. He required major surgery on three occasions to alleviate the problem and his handling of the Suez crises has been directly linked to the medication he was taking to alleviate postoperative symptoms (Dutton 1997). Having set the context, the presenting symptoms of the disease that Eden first presented with could be recounted, then a lesson in the anatomy and physiology of the gallbladder and cystic structures. Trainees could then be shown how the operation is approached and performed using the traditional open surgical approach and what caused the complications in Eden's case and how alleviation would be approached. This would then lead on to the development of laparoscopic cholecystectomy and the complications that ensued with its introduction. The important anatomy, physiology, signs, and symptoms information about cholecystectomy is tagged on to the information about Anthony Eden. This otherwise bland information is made more colorful and hence more memorable by real world association and implications for a great British Prime Minister.

Pre-learning: Procedural Memory

Procedural memory is our memory for how we do things. In Chap 4 we described the process of skill acquisition outlined by Fitts and Posner (1967). They proposed that learning a new skill involves three stages. The Cognitive stage involves the learner developing an understanding of what the skill comprises. This process involves understanding the units of behavior and performance characteristics in the sequence that occur in the construction of a skilled performance. In the second stage, the Associative phase, they practice and hone performance based on what they know, and their experience in the application of what they know, until efficient patterns of performance emerge. It is during this stage that ineffective characteristics are dropped and performance starts to become automated. Larger and larger chunks of activity are put together to form smoothly executed sequences. It also becomes possible to carry out other tasks at the same time, leading to better dual task performance. This is an extremely important aspect of skill acquisition and is crucial for the intraoperative performance of safe surgery. An important aspect of the training of surgeons is to have as much of their procedural skills developed to the stage where they are automated before they enter the operating room. The reason for this is simple; the performance of clinical surgery makes multiple cognitive demands particularly on attentional resources, i.e., what the surgeon can consciously attend to by automating where possible skills such as, psychomotor coordination of instruments. It leaves more attentional resources available for higher-level tasks such as intraoperative problem solving.

The final phase outlined by Fitts and Posner (1967) was the Autonomous phase. This is when the learner perfects their skill usually with practice. It leads to what many individuals consider the essence of what is meant by skilled performance, i.e., performance that is automatic, unconscious, or instinctive. None of these descriptions stand up to close scrutiny given the difficulties in operationally defining "automaticity" but they convey the idea of performance that is carried out in a very different way from that of previous phases of skill acquisition. Not all performances evolve to this level of skill and many will remain at Phase 2. The differences between Phases 1 and 2 are that the learner "knows that" and in Phase 3 they "know how." This difference is probably a good example of what best distinguishes between declarative (Phase 1 and 2) and procedural knowledge (Phase 3). The fundamental idea is that as a skill is learned there is a change in the type of knowledge that underpins performance. The early stages (Phase 1 and 2) are typified by a reliance on declarative forms of knowledge and on explicit rules for carrying out the task. However, as the learner becomes more familiar with the task and develops efficient and effective performance sequences, they begin to refine their performance to suit themselves. They can perform the task to a high level of quality even in the presence of distracting events. Performance seems almost immune to disruption and they have the ability to accurately prioritize and sequence events during un-planned-for intraoperative events. Skill application appears to be done without conscious awareness almost as if the knowledge has been compiled (just as in computer programming) into something akin to machine code (Anderson 1993).

As mentioned, one of the advantages of developing skills to the point where they are automated means that there are more attentional resources available to allocate to other aspects of task performance. However, one of the disadvantages is that the declarative knowledge that well practiced skills were based on are lost to the practitioner. Unfortunately, this means that the skilled practitioner may not necessarily make the best trainer. It also means that they may have difficulty identifying performance characteristics that need to be operationally defined (see Chap 8). However, this is not an absolute situation and many surgeons can be trained to identify aspects of performance that they have automated. Another problem associated with skills automation is probably more serious and that is the problem of acquiring bad habits during training. This is a particular weakness of poorly designed or badly monitored simulations. For example, some virtual reality endoscopy simulations allow the trainee to pass the endoscope straight down past the vocal cords into the esophagus. Unfortunately, in real patients, navigating the endoscope past the vocal cords is rarely straightforward. If the trainee learns on the simulator that this part of the task is straightforward that is precisely what they may do on the patient on whome they perform the procedure thus risking an injury.

Memorizing Strategies

One of the goals of lecturers, handouts, and notes is to help an individual to remember the material they have learned. This material in turn will be used to inform the trainee about appropriate aspects of the surgical procedure. Cognitive psychologists have built up a considerable understanding of useful strategies for helping people to remember information they have learned. This knowledge is based on over a century of quantitative research.

Organization

Miller (1956) developed the term "chunking" in a classic paper concerning the capacity of immediate memory. In this study, he asked subjects to remember strings of the digits. In keeping with what was known at the time about the usual span of apprehension, the subjects recalled only about seven digits correctly. However, Miller also showed that people can remember a greater number of digits by organizing the digits into higher-order groups, i.e., 0911, 2004, 2506, 1959, 1690, 1966, 1603, which consecutively are the date of the World Trade Center terror attack in New York, the birth year of one of our children that was born in the USA, the date of birth of one of our children, the date of birth of one of us (the prettier one!), the date of the Battle of the Boyne, the year England won the World Cup and the year Queen Elizabeth I died. Miller argued that the chunking method worked by allowing the subjects to use their limited cognitive capacity more efficiently. This finding is important because it established that human beings were limited capacity information processors. The estimated capacity of immediate memory has been established as 7 ± 2 chunks, but this is probably best viewed as a rough approximation. This is because the capacity of immediate memory reflects the limits of a potential capacity and because the amount of capacity available can vary depending on the type of task, and the level of fatigue; therefore, the capacity of immediate memory can vary across situations (Baddeley et al. 1975). The most that we can say is that the capacity of immediate memory is limited but not fixed and that organization facilitates immediate memory. In presenting information on an e-learning platform, it is best to impose organization on the material to be learned and remembered. In operative surgery, most procedures lend themselves to ready organization in terms of anatomy and physiology, signs and symptoms, diagnosis, intervention and follow-up. The surgical procedure itself also lends itself to the process of chunking, e.g., preoperative preparation, the procedure itself, and postoperative management. Performance of the procedure is also usually already organized into manageable chunks by experienced surgeons. Surgeons have already worked out the steps in the procedure and they are likely to allow trainees to perform certain parts of the procedure depending on their level of training and experience. These naturally occurring organizational chunks should be utilized in the organization of e-learning information. If there is no agreed-upon intraoperative steps for the surgical procedure, a set of procedure steps should be imposed for the purpose of facilitating learning. However, it should be pointed out to the learner that there is no uniform agreement on the steps or the order of the steps in the procedure that they are being taught. An even better strategy would be to have agreement among surgical supervisors of a "reference procedure" approach within the surgical training program. This would ensure consistency from online learning, the skills laboratory training, and intraoperative supervision. After the trainee is comfortable in the performance of the procedure, they can hone their procedural skills based on the wisdom of their more senior supervising surgical colleagues.

Understanding

An optimal approach in trying to memorize something is to first understand it. A good way to do this is to try helping the learner make connections between what they have already learned and experienced and the new information. As we have pointed out earlier, episodic memories (that is memories idiosyncratic to the individual) are usually remembered better than semantic memories. The easiest way to do this is to help the learner relate the new information to what they already know. Educationalists constructing the e-learning package will have a very good idea of what the learner knows based on the level of training and the contents of the program curriculum which is almost certainly based on a national or international curriculum. Not only should the designers of an e-learning package consider what knowledge and experience the learner brings to the learning situation, but they should also check the understanding of the learner as they work through the e-learning package. This type of assessment (e.g., either formative or summative) is important not just for the quality assurance of trainee performance, but they can also be used to ensure that the trainee does not progress to more difficult parts of their online education package without a thorough understanding of the material they have already covered. If this is not done, the trainee will find subsequent parts of the learning increasingly more difficult and it also increases the probability gross misunderstandings of the material being learned. It is very important to avoid a chain of apparently inconsequential misunderstandings and errors which could lead to catastrophic consequences for a patient. As we have pointed out earlier, it is very easy to develop bad habits and bad behavior. Once these have become automated and integrated into the knowledge and practice system of the individual doctor, they are very difficult to extinguish. It is better to ensure that they do not occur in the first place and a way to avoid them is with formative assessment. We shall say more about assessment of e-learning performance later.

Graphic Organizers

These tools help the learner to see things as they are trying to learn and they also help organize information. There are many different types of strategies that can be used as graphic organizers. These can be as simple as a PowerPoint slide with a diagrammatic representation of the anatomical structure or the disease process that the individual is trying to learn. It could be an animated PowerPoint presentation showing cause and effect relationships or a cycle of relationships. Graphic representation of information is easier to recall for a number of reasons. It helps to organize the information into a coherent format. It can also present and summarize the information in an anatomically correct visual format, which has greater power to convey knowledge than words.

Visualization

Visualization means that the learner is helped to see a mental image of what it is they are trying to learn. Developing mental imagery can be facilitated with the use of animated films or actual video recordings of what it is we are trying to get the learner to remember. If a picture paints 1,000 words, animated films are even better. The availability of these demonstrations has become extremely common with the increased power of computer presentations and the amount of information that can be transmitted in real time over the Internet. Films have the advantage of organizing information to be learned and presenting it in an interesting way, showing the order and sequence in which events occur and also showing the context in which they occur. As such, they are very powerful aids to help the learner remember complex information. Another advantage of this approach is that it explicitly relates information to be learned with that which has been very well learned, probably years ago, e.g., anatomy and physiology. Establishing relationships between new ideas and previously existing memories dramatically increases the probability that the new information will be remembered. The more interesting the visualization strategy, the more coherent and integrated it is, the greater the facilitation of memory storage. Developing a coherent strategy is not complex or difficult; however, it does take forethought, organization and improvisation.

Repetition

The more times repeats something, the better memory will be for that information. However, each time that information is gone through, a different angle should be used so that the learners are not just repeating exactly the same activity. Varying the approach will create more connections in long-term memory. Frequency of repetition affords the opportunity for the material to become better integrated and associated with information that has already been learned. Retention of information depends on the elaborateness of its processing. The elaborate processing can occur by relating incoming items to other incoming items as well as information that has been learned previously. In studies of free recall, people spontaneously organize words into groups, and this elaborate processing was correlated with higher levels of retention (Anderson and Reber 1979). Further retention can be facilitated by inducing trainees to organize the information themselves so that it is distinctive; their understanding of it is complete and idiosyncratic.

Formative Assessment

In 1967 Michael Scriven coined the terms "formative" and "summative" evaluation (Scriven 1991). The purpose of formative assessment is to enhance learning and not to allocate grades. Formative assessments are considered part of instruction and instructional sequence and are thus non-threatening methods used to score performance rather than to grade it. Results of formative assessment given immediately enhance learning. Thus, formative assessment used in an e-learning package provides a very powerful learning tool. Assessments should occur when content is being taught and learned and should continue throughout the period of learning. Formative feedback lets the trainee know how well they are doing and this information should also be available to the trainer. For the trainee, it reinforces their progress and rewards success. For the trainer, it gives them valuable information on how well a cohort of trainees are progressing but it also highlights material that may need to be revisited, to provide better explanation or subsidiary information. Formative assessments also serve another function, and that is enforced repetition of material that is being learned or has been learned. Thus, formative assessment facilitates the "effortful" recall of learned information which encourages the elaborateness with which information is encoded in long-term memory. Furthermore, the more frequently a piece of information is retrieved from long-term memory in different contexts, the easier it is to retrieve that information on future occasions. Figure 9.2a and b gives examples of what an online component of teaching and assessment might look like. Figure 9.2a (the teaching slide) shows the anatomical landmarks of the colon that the trainee should know and be able to freely report before performing the examination on a real or virtual patient with a flexible endoscope. In Fig. 9.2b, the goal is to assess the trainee's knowledge of anatomical landmarks of the colon. The landmarks are highlighted by the arrows and the task for the trainee is to drag with the computer mouse one of the labels on the right-hand side to the appropriate arrow on the left-hand side of the figure. If a trainee drags a landmark name to the correct position on the figure, the label stays in position indicating that they are correct. In contrast, if they drag a landmark name to an incorrect position, it immediately and automatically returns to the list of landmark names, indicating that the attempted positioning was wrong.

Memorizing: Stress and Sleep

It is important that the context in which the current of information is taught to individuals is taken into consideration. This is particularly so for surgeons. It has been found that declarative information is less likely to be recalled if learning is

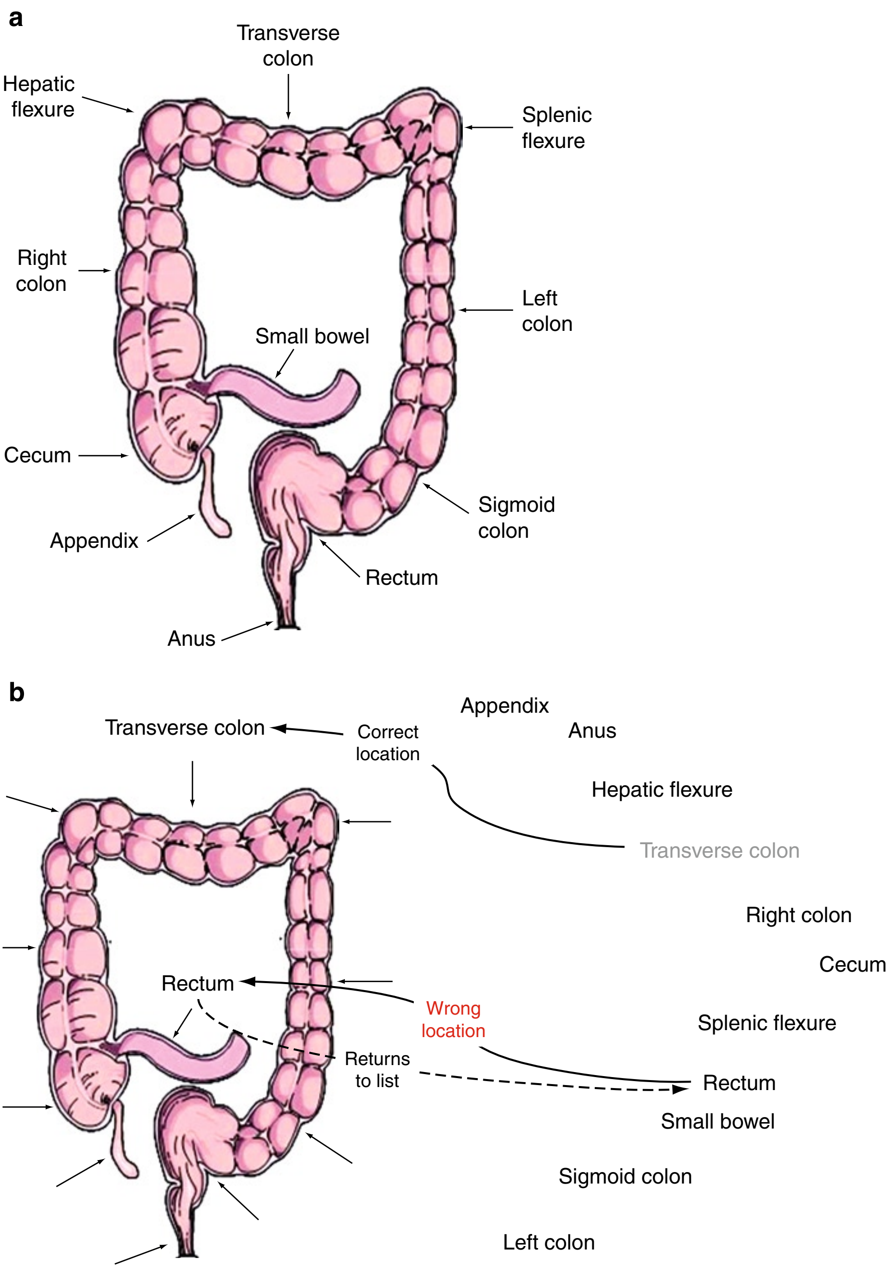

Fig. 9.2 (**a**) Anatomical landmarks of the colon for colonoscopy training. (**b**) Anatomical landmarks of the colon for colonoscopy training formative assessment component

followed by a stressful experience. Surgical trainees who attend a very interesting and informative grand rounds and then go immediately to the operating room or a busy emergency room are less likely to remember the information they learned from grand rounds, than those who are on a study day (Lupien et al. 1997). In contrast, the information learned is probably best remembered after a good night's sleep. It was believed for many decades that sleep played an important role in the consolidation of declarative memory. Memory consolidation is a category of processes that stabilize a memory trace after the initial acquisition (Dudai 2004). Although the relationship between sleep and remembering has been known for centuries, the term "consolidation" is credited to the German psychologists Georg Elias Müller and Alfons Pilzecker. They outlined the idea that memory takes time to fixate or undergo "Konsolidierung" and it is discussed in relation to their studies conducted between 1892 and 1900 (Dudai 2004). As noted in Chap 3 sensory stimuli are encoded within milliseconds; however, the long-term maintenance of memories can take additional minutes, days, or even years to fully consolidate and become a stable memory (i.e., resistant to change or interference). Therefore, the formation of a specific memory occurs rapidly, but the evolution of a memory is often an ongoing process. These findings help to account for an observation that post-sleep performance of some trainees in the skills labs seem to show significant improvement in the absence of practice. It has been suggested that the central mechanism or consolidation of declarative memory during sleep is the reactivation or reverberation of newly learned memories. The idea originates from Donald Olding Hebb's (1904–1985) theory that a cell, functioning as a whole unit, continues to respond or reverberate after the original stimulus that initiated its response has been terminated. More recently, it has been suggested that the central mechanism for this process of declarative memory consolidation during sleep is the reactivation of hippocampal memory representation. Neuropsychological and neurophysiological PET studies have now shown that the newly learned memories are reactivated during sleep and through this are helped consolidate (Ellenbogen 2005). The implications for these findings are obvious and support the use of e-learning platforms for learning didactic information remote from a stressful environment by a well-rested trainee. For surgical device companies that run courses for surgeons on how to use newly developed devices or a novel evolution of a common surgical device, these findings probably make less comfortable reading. These courses are usually run over 2 days and involve both didactic and technical skills training with a course dinner in the intervening evening. Research has shown that even moderate alcohol consumption shortly before bedtime catalyzes disruptions in sleep maintenance and sleep architecture. This can have deleterious effects on knowledge storage, maintenance, and retrieval. This means that minimum alcohol consumption and early to bed might make these courses less attractive to both senior and junior surgeons. However, these variables are much easier to control in the comfort of the trainee's own accommodation, i.e., learning at home.

Procedural Training

In a virtual reality simulator or emulator, the handles of real instruments are used as effectors for virtual instruments to interact with virtual tasks or simulated tissues. The question arises: when does an online education and training package seep into the function of a simulator. Consider the following example. In Fig. 9.3a–c, we have

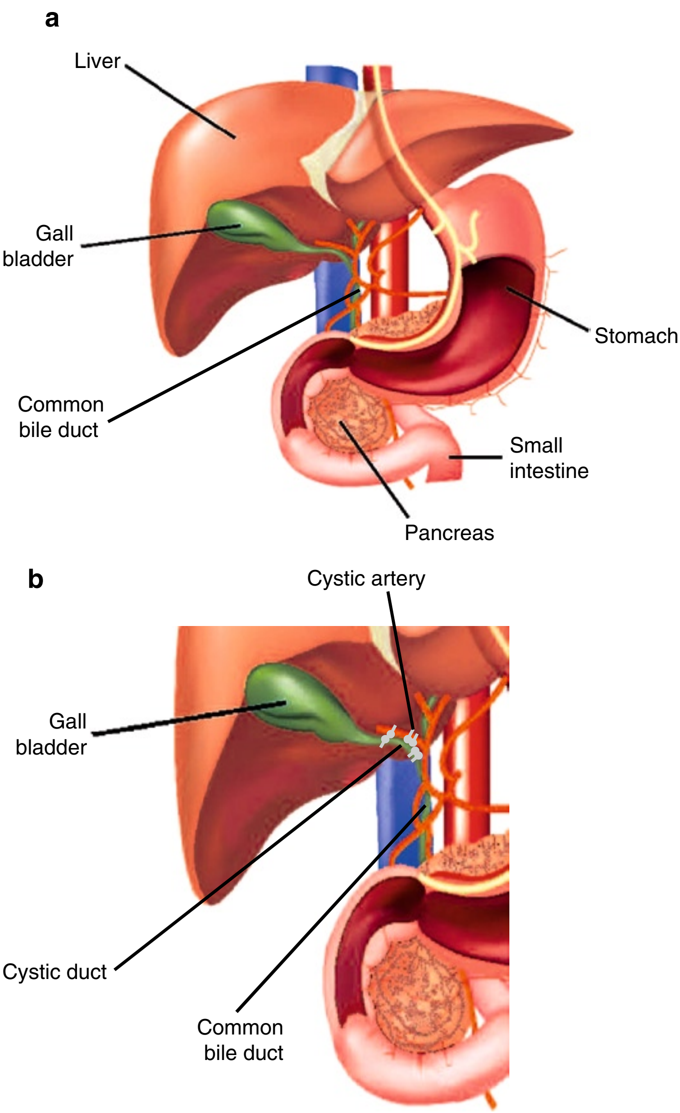

Fig. 9.3 (**a**) and (**b**) Diagrams illustrating the anatomy of the gallbladder in relation to other organs and clips application over the cystic duct and artery during cholecystectomy. (**c**) Figure illustrating the anatomy of the gallbladder and the trainee is asked to apply the surgical clips over the cystic duct and artery using the computer mouse

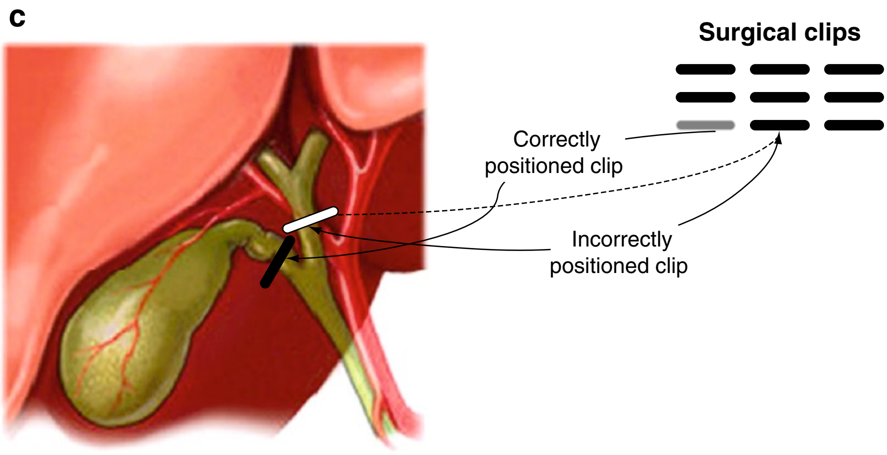

Fig. 9.3 (continued)

presented the anatomical organs in close proximity to the gallbladder. We have also shown the structures of the gallbladder, and in Fig. 9.3b, we have shown the correct location of surgical clips on the cystic duct and cystic artery for safe dissection. In Fig. 9.3c, we have presented the trainee with a novel image of a gallbladder and cystic structures and tasked them with placing the appropriate number of surgical clips on the cystic structures before they can be safely dissected. The task could have been made slightly more difficult by requiring the trainee to choose the appropriate clip applicator from a range of surgical tools. The description of the task could also have required the trainees to identify where on the cystic structures they would dissect, i.e., clip the cystic duct with three clips and then dissect between the 2nd and 3rd clip (on the gallbladder side of the second clip). They might have done the cystic duct before the cystic artery. This then could have been assessed much the same as the task described in Fig. 9.2b. The appropriate regions of on the cystic duct and the cystic artery appropriate for clipping and dissection could have been liberally defined with spacing between clips. The area of dissection between clips could also have been defined and errors enacted by the trainee could have been immediately fed back to them had. Is this online education or procedural training? We would suggest that this is the start of procedural training and that in reality there is no clear demarcation boundary between what is education and what is training. All of these aspects of education and training lie on a fidelity continuum where possibly the lowest level of fidelity might be book chapters or text and an intermediate level of fidelity might be a MIST VR type simulator all the way up to the highest fidelity training opportunity, i.e., a real patient. The goal of the surgical curriculum is the training of safe and effective skills for operating room performance. Whether something is taught online, in the classroom, in one-to-one tutorials or in the skills laboratory is somewhat academic. They should be taught and trained in the most efficient (including cost-efficient) way possible. The question should not be should we do it, rather it should be what do we want to achieve by using this education/training platform and is this the best use of the trainers and trainees time? We emphasize trainer's time because e-learning modules will require preparation and even with dedicated technical support, they will still require considerable academic effort to prepare or storyboard the didactic material, validate it, and then monitor its implementation and the trainees progress. Validation of these systems is essential and these studies should be conducted to the same level of rigor as VR simulations (Chap 7).

Trainees need to be presented with multiple examples of the same task, which ideally should increase in complexity commensurate with their passing formative assessments. Subsequent tasks might include good quality images of the cystic structures preoperatively. The task of trainees would be to identify the cystic structures for exposure, clipping, and dissection. The reason for this is simple: it has been proposed that one of the major reasons for complications associated with laparoscopic cholecystectomy is failure to accurately identify the cystic structures (Way et al. 2003). Training could continue online until the trainee was able to accurately identify cystic structures consistently. This would considerably improve their operative safety.

The facility of being able to link laparoscopic instruments in a MIST VR type frame to the Internet to perform virtual reality tasks is not widely available. However, it is possible to perform certain basic tasks using a simple computer mouse that almost certainly will have beneficial effects that transfer to skills laboratory training sessions. For example, in a study by Jordan et al. (2001), they trained subjects to trace a groove in a "U" or a "Z" shape with a stylus. The end of the stylus was monitored by the subject via an endoscopic camera. This meant that the stylus had a "fulcrum" on it as seen in laparoscopic surgery instruments. If they touched the edge of the groove, an alarm sounded and this was classified as an error. The reason these two shapes were chosen was that the "U-shape" had one fulcrum along the *x*-axis and the "Z-shape" had two. They found that subjects who trained on the "Z-shape" performed significantly better on a novel laparoscopic task. They concluded that this was because the "Z-shape" training group had more exposure or training to the *x*-axis fulcrum which transferred to improved performance in the novel laparoscopic task. In an online training component, instead of using a stylus, a computer mouse could be used instead. The goal of this task would be to help the trainee to automate the apparent movement inversion on laparoscopic instruments caused by the fulcrum effect. Trainees could trace a variety of shapes where the action of the computer mouse has been inverted, i.e., the trainee moves the computer mouse to the right and the arrow on the screen moves to left and vice versa. The same would also apply to *y*-axis movements. In another study using the same task, researchers found that trainees benefited most from the feedback they had on the accuracy of their stylus tracking performance and transfer of training to a novel laparoscopic task was greatest for the group who had the most performance feedback during training (Van Sickle et al. 2007). The data from these studies tell us that considerable benefits can be accrued from skills training in fairly basic tasks. These data would suggest that a simple training task could make skills training on their simulation in the skills laboratory much more efficient as subjects would automate to the fulcrum effect much quicker after pre-training. As suggested earlier, educationists should continuously question how, when, and where is the most effective and efficient platform to deliver education and skills training. It is our belief that e-learning is currently underutilized and could be used much more effectively and probably less expensively to supplement skills laboratory training and make it more efficient. It is highly probable that e-learning could be effectively used as part-task trainer. Which parts of a particular task are suitable for part-task training could almost certainly be worked out during the task analysis process of a given procedure for the identification of performance metrics. It has been our experience that while addressing these questions, the task analysis team usually considers training platforms as well.

Observational Learning

"Live" Cases: Basic

A very powerful learning strategy touched on briefly in Chap 4 is observational, vicarious or modeling (Bandura 1982). Observational learning occurs when an individual observes another person (referred to as the model) engage in a particular activity. The observer sees the model perform that activity but does not engage in that activity, for example, watching another surgeon perform a specific procedure. The observer learns the behavior merely by watching the model. The modeled behavior is assumed to be acquired by the observer through cognitive or covert coding of the observed events. Unlike traditional learning situations, there are no active contingencies impinging on the learner/observer. Observational learning is assumed to have taken place when the observer exhibits performance characteristics which have not been explicitly trained. This very powerful education and training method is widely used in medicine from ward rounds in the morning, to observing in outpatient clinics and in the operating room. However, as highlighted in Chap 4, not all behaviors modeled by more experienced surgeons are necessarily behavior that we would wish the trainee to develop, i.e., some senior surgeons may have developed poor procedural habits! E-learning affords an ideal opportunity to use this powerful learning methodology minus the bad habits.

Given the availability of video recording facilities in operating rooms and other centers where procedural care is delivered, recording index cases for use on e-learning packages should be relatively straightforward. The training program would not require a large volume of these procedure recordings; however, they should be chosen strategically. Furthermore, it is probably inefficient to show the entire procedure and it would probably be more beneficial to edit the recording so that it correlates well with the organizational structure that has been detailed in the didactic procedure outline. This means that the recorded procedure should follow in the same sequence order or procedural steps as the didactic module states. This reinforces the cognitive model that the learner has for the procedure and helps to consolidate the information that they have acquired with the new information they get from the video recording. Although it is common for very experienced or expert surgeons to talk through the surgical procedure as they are performing it, this is probably not ideal for general-purpose teaching and training. A better alternative would be to get the operating surgeon to do a voice-over of the recording. This voice-over should be clearly scripted and correlate closely with the organizational and procedural structure outlined in the didactic component. This would be relatively straightforward if the operating surgeon has been involved in the preparation of the didactic component from the outset. It is important that education and training materials concord as closely as possible so as to facilitate learning.

Live Cases: Advanced

The edited and live cases, just outlined, are probably best utilized for basic surgical training. Recorded cases of more advanced procedures for more senior surgeons would also be a useful adjunct for training and continuing professional development. The case mix that surgeons in training or indeed surgeons in practice are going to encounter in the future will continue to reduce (Crofts et al. 1997). This is a consequence of reduced work hours, more skills training taking place online, in the classroom or the skills laboratory and increased hospital and unit specialization. On the one hand, this will have beneficial effects for the patient as the surgeon has more experience and a greater volume of similar cases which can only improve the quality of care. However, we believe that the constriction on the variety and mix of cases that consultants and probably trainees are exposed to may have negative consequences on the development of wisdom. Many of our surgical and medical colleagues argue that the most important attribute that trainee surgeon can develop is decision making. Decision making is a constituent part of a spectrum of performance characteristics that constitute a "good" surgeon or a "good" doctor. Wisdom is a deep understanding and realizing of people, things, events, or situations, resulting in the ability to choose or act to consistently produce the optimum results with a minimum of time and energy. Wisdom is the ability to optimally (effectively and efficiently) apply perceptions and knowledge to produce the desired results. Wisdom is comprehension of what is true or right coupled with optimum judgment as to action. In Chap 8 we outlined the efforts made by the major medical and surgical training organizations around the world to defining competence and competency. However, we believe that wisdom is the overarching goal which these organizations aspired to train. While they have done a relatively good job of describing the constituent parts of a good doctor, there is concern that the sum of the parts may not add up to what is hoped, i.e., a wise doctor. We will return to the issues of wisdom acquisition in Chaps 11 and 12.

Learning Management System

A learning management system (LMS) is software for delivering, tracking, and managing training/education. LMSs range from systems for managing training/educational records to software for distributing courses over the Internet and offering features for online collaboration. Probably the single most important decision in this process and also one of the most difficult decisions will be about the LMS. There are many commercially available LMSs and it is difficult to choose between them. The decision about which learning management system to choose should not be taken by educationalists in isolation from other members of the team. Just like decisions about metric development, the decision about which LMS to choose should be informed by a computer scientist who is very familiar with the different systems that are commercially available. This individual should also be very well acquainted with the needs of the surgical training program. The surgeons on the decision team should have a good idea about the types of material that they wish to deliver on an e-learning platform. A behavioral scientist or psychologist should also be included in the decision-making team as they would have a fairly good knowledge about the types of metrics that they wish to implement in the formative and summative assessments and the sort of data that they want reported back to the course administrator. The LMS chosen to deliver and manage the e-learning content should make considerable time savings for the academics providing the course content. This may not be the case in the short term but it certainly should be a medium-term goal. A learning management system should not simply "look pretty." It should be an efficient and effective tool for the delivery and assessment of online learning content. Most of the commercially available LMSs are more than capable of delivering content. However, close scrutiny should be paid to the ability of the system to deliver and to manage formative and summative assessment. If this aspect of the LMS is not chosen well, the academic program could end up with a system that is not much more functional than a DVD. The same rules for choosing a simulator apply to choosing an LMS. Purchasers must look beyond the sales pitch and ask to see working examples of systems that would be ideal for their purposes or aspects which might be suitable for online education and training of surgeons. Unfortunately the commercially available LMSs that do exist have not been designed or developed with the functionality that we have outlined in this chapter. This does not mean that it cannot be developed relatively quickly.

The surgical training program would need to know or at least be confident that the person completing the online education and assessment units was the person that it was supposed to be. This is not a difficult feature request; it may have to be implemented in a novel way, such as intermittent requests for identity confirmation. The LMS should also provide a straightforward course authoring methodology that is relatively easy to learn for the multiple academics that will be using the system and contributing to content development and content libraries. The LMS should also provide a relatively straightforward content management system which is easily configurable for multiple specialties. It should also provide straightforward administrative reporting and tracking of individual trainees and groups of trainees as they progress through the content. Very importantly, the LMS should administer and manage the formative and summative assessment process. This means that the system also needs to be able to manage the content library and exam engine. Another feature, which we suggest is crucial, is ensuring that trainees demonstrate the performance criterion or proficiency level before being allowed to progress. This process should not be managed on a day-to-day basis by an academic supervisor. It should be overseen by an academic supervisor whose function is to identify individuals who are struggling with module content and to investigate and intervene when appropriate. Likewise, the LMS would manage trainee course compliance and more importantly failure to comply. Over the longer term, the system should track individual and group performance through the different years and modules of the course. This type of LMS use is relatively novel, particularly in high stakes education and training programs such as surgery. That means that results on almost everything that is done with the LMS system need to be reported in the peer-reviewed literature, particularly on the reliability and validity of the system and the amount of transfer of training. Currently, we can only guess what the transfer of training rate might be. In an ideal world, the most valuable data that could be reported on are gross system errors. However, we are not confident that this information will be reported completely and publicly.

Summary

E-learning platforms hold enormous potential for the delivery and management of curriculum material in surgical training programs. They should not be used as a novel way of delivering a traditional lecture. The power and flexibility of e-learning should be harnessed to augment and facilitate the learning process based on sound principles. These dictate that material to be learned is organized in a format that relates to previously learned material and requires the learner to interact with the material and to problem solve. Learners' performance on these problem solving or assessment exercises should be assessed formatively on an ongoing basis with feedback given to the learner in a proximate fashion, i.e., close to performance. There should also be a summative assessment component to the learning process and individuals should not be allowed to progress until they have demonstrated the requisite performance criterion level. This will have implications for satisfactory trainee progress which should be implemented and managed with a Learning Management System (LMS). These LMSs need to be validated to the same level of rigor as VR simulations.

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