E-Learning

is there anything special about the "e"?

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ABSTRACT E-learning has been widely utilized in medical education and suggested by some proponents to represent a fundamental advance in educational methodology. We challenge this conclusion by examining e-learning in the context of broader learning theories, specifically as they relate to instructional design and methods. Core tenets of educational design are applied to e-learning in a unified model for instructional design, and examples of e-learning technologies are examined in the context of medical education, with reflections on research questions generated by these new modalities. Throughout, we argue that e-learning is a tool that, when designed appropriately, can be used to meet worthy educational goals.

SHORTLY AFTER THE ADVENT of the computer, educators began using this powerful tool to facilitate learning. Medical education has certainly capitalized upon this technology, witnessed by the growing number of online tutorials, discussion boards, virtual patients, syllabi, and resource repositories. With this growth, learning with computers—or "e-learning"—has seemed to take on a life of its own, spawning not only special sessions within conferences for medical specialty groups, but also specialty groups devoted exclusively to medical e-learning, journals devoted to innovations and research in the field, and growing numbers of educators seeking to advance the field through scholarship.

But is this distinction warranted? Does e-learning merit classification as a sep-

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arate entity within medical education? And perhaps more importantly, is this separation even desirable? We argue that this separation is in fact arbitrary. E-learning is only a tool—a powerful tool indeed, but not an end in itself (Cook 2005b). While specialization in the use of technologies is inevitable, we suggest that the educational principles relevant to the design of effective e-learning are no different than those at work in traditional educational settings. In the context of these principles we discuss some of the most common e-learning modalities, along with the challenges and areas for future research associated with each.

Is E-Learning Superior to Traditional Instructional Methods?

E-learning advocates tout advantages of e-learning over other instructional methods, including enhanced knowledge gains, efficiency, motivation, engagement, retention and transfer to new settings (D. Clark 2002). However, it is important to recognize the limitations of the research upon which these claims are made (Cook 2005b; Tallent-Runnels et al. 2006). Specifically, in every example we have seen in which e-learning "proved" superior to a traditional instructional setting—regardless of the outcome—the e-learning intervention employed substantially different instructional methods compared to the traditional arm. It is not surprising, for example, that learners who control the pace of the learning session take less time than those who sit in the lecture hall; that those who see a picture of the cranial nerves have a better understanding of their organization than those who read a text; that those who watch a video clip in which a patient is informed of his cancer diagnosis feel more empathy than those who read about the same scenario; that those who listen to recorded heart sounds are subsequently able to recognize them better than those who read written descriptions of the same; or that those who have the opportunity to repeat a course on demand will retain more than those who sit through a course only once. However, each of these methods—self-pacing, pictures, patient observation, auscultation, and repetition—could all be implemented in a traditional setting as well. Yet rarely is comparison made between an e-learning intervention and a traditional intervention using similar instructional methods, and when such comparisons are made the results invariably show no significant difference (R. E. Clark 1985; Cook 2006; Tallent-Runnels et al. 2006).

This "no significant difference" phenomenon has been well studied. The present infatuation with e-learning was previously manifest with phonographs, television, film strips, and other technologies earlier in the 20th century (Clark 1983). In each case, initial enthusiasm led to similar claims of superiority, but then as now, the comparisons were decidedly unfair—the game was rigged in favor of the new technology. This does *not* mean that new technologies have nothing to offer. On the contrary, e-learning makes the implementation of many instructional methods easier. It is easier to self-pace an e-learning intervention than a lecture. It is easier to show full-color pictures on a computer than on a printed handout. It is easier to show a video clip of an interaction between a physician and a standardized patient than to have the standardized patient return each time the course is taught. It is easier to put audio clips of heart sounds on the Internet than to find the same heart sounds anew each time a course is taught. And it is easier for a learner to revisit an e-learning course than to teach the course with a live instructor multiple times. In each case, however, the computer does not do anything magical to enhance learning per se, but rather facilitates the use of instructional methods that are already known to be effective.

Ultimately, the rationale for using computers in education comes not because of any inherent instructional advantage but because computers facilitate the use of effective instructional methods. As an example, over the past 15 years film slides have virtually disappeared in favor of PowerPoint. Is PowerPoint an inherently more effective means of instruction? Unlikely. Rather, the advantage of PowerPoint lies predominantly in the ease, low cost, and speed with which slides can be created and updated; the portability from the lecturer's office to the site of the presentation; and the fact that PowerPoint slides do not get jumbled-up when the slide carousal tips over. Granted, multimedia (audio and video clips) can be integrated with PowerPoint presentations, but so can more traditional audio recordings and video clips be integrated with a presentation using traditional slides. Few would argue that PowerPoint is not superior, but this superiority derives exclusively from practical advantages and not from any inherent superiority in instructional efficacy.

Thus, we believe the argument of superiority, inferiority, or equivalence is moot. It is a far better investment of resources to investigate "what works?" in e-learning, rather than trying to justify its existence. The advantages and disadvantages of e-learning have been addressed in depth elsewhere (Cook 2007). This article will explore the hallmarks of good learning strategies relevant to the design of effective e-learning.

Instructional Design for E-learning

Numerous books, monographs, and articles have been written on how to develop and implement e-learning interventions. Unfortunately, recommendations grounded in evidence and research-based theories constitute a minority, with most published works consisting of practical wisdom, anecdote, and enthusiasm for technology. Indeed, many recommendations put the cart before the horse—encouraging use of new technologies for technology's sake, rather than because of any grounding in effective instructional design. Below, we discuss a selection of learning principles that inform instructional methods and that in turn form the foundation for effective instructional design. In each case, we have attempted to select elements that have grounding in research and also lend themselves to practical application.

Core Tenets of Learning

Four tenets should be kept in mind when considering how people learn, with a view towards how teachers may better facilitate learning. Although the evidence is incomplete, it appears that these tenets apply to the development of both clinical reasoning and technical skills.

The first tenet is that learning entails far more than mere accumulation of information. Rather, true learning occurs as learners organize and link information together in a meaningful way (Bransford, Brown, and Cocking 2000). The emphasis on meaning is essential: new information only becomes useful as learners integrate it with prior knowledge and past experiences (Dewey 1998), a process also known as elaboration. Elaborated knowledge has been called "the key to successful diagnostic thinking" (Bordage 1994). Although a good teacher can facilitate the process, in the end it is the learner who constructs his or her own knowledge.

The second tenet is that knowledge and skills are inextricably linked (Norman 2005; Norman et al. 2006). Clinical problem solving is not a unique skill that can be learned or taught independent of formal and/or experiential knowledge. For example, both junior medical students and expert clinicians use similar reasoning strategies when interviewing patients with uncertain diagnoses not previously encountered. For common diagnoses, however, experts exhibit very different reasoning strategies, moving more rapidly to the correct diagnosis by recognizing paradigms learned from experience. More importantly, success on one problem is a very poor predictor of success on unrelated problems. Thus, the problem solving "skill" seems to be something that is learned rather early but must be accompanied by domain-specific knowledge in order to be used effectively. Similar domain specificity has been found for technical skills (Norman et al. 2006). The implication for teaching is that we should not focus our efforts on trying to teach some generic problem-solving skill but should rather work to integrate problem-solving strategies as they relate to specific content domains.

The next core tenet follows, namely that learning must facilitate subsequent transfer (Bransford et al. 2000). By transfer we mean that what has been learned in the classroom or in the context of one specific case should transfer or translate to a real or different patient or another clinical setting. While we wish that transfer were easy, abundant evidence suggests that it is in fact very difficult. For example, students will pay inordinate attention to a suggested diagnosis or to irrelevant details such as name, occupation, or a specific clinical setting, at the expense of more salient details of medical history, exam findings, or test results (Leblanc, Brooks, and Norman 2002; personal communication, K. Dore 2006). Furthermore, knowledge is frequently inaccessible—we might have learned something and we might even know that we learned it, and yet be unable to draw upon that knowledge in the moment of need. This may be less of a problem if we recognize the knowledge deficiency, but often it is simply a matter of failing to recall the information without an explicit or personal awareness. It is not entirely clear how to overcome the problem with transfer, but experts suspect the solution relates to distributed, deliberate practice. Ericsson (2004) has noted similarities among expert performers in chess, music, and sports—namely, experts in these fields achieve their level of expertise through thousands of hours of dedicated practice. This practice is most efficacious when it is explicitly designed to push the limits of the expert's performance and is conducted under the supervision of a coach or a teacher who provides continuous constructive feedback. In addition to deliberate practice, learning is most effective as smaller doses distributed over an extended period of time rather than concentrated into one or a few intense experiences. The same principles apply to acquisition of technical skills in medicine (Norman et al. 2006). It is not as clear how these findings apply to clinical reasoning, but we presume that the principles hold true and note that they harmonize well with the previous core tenet. Expertise in medicine will be best developed when multiple cases representing varied contexts are deliberately structured in a manner to optimize learning and are solved under the direction of teachers who provide corrective feedback.

The fourth core tenet is that of cognitive load. Cognitive load theory proposes two centers for human memory: working memory and long-term memory (Clark, Nguyen, and Sweller 2006; van Merriënboer and Sweller 2005). Working memory is the area of the brain that processes information received from the environment. Information probably stays in the working memory for at most 20 seconds before it is either lost or encoded in the long-term memory. It appears that the working memory can only accommodate approximately seven pieces of information at a time, and this limit in working memory forms the basis for cognitive load—namely, if the capacities of working memory are overwhelmed, any additional information will be lost. On the other hand, long-term memory has no known limitations. Once working memory has processed information and transferred it to the long-term memory, that information is (apparently) available forever—within constraints, of course, of limitations on transfer as noted above. Thus, managing cognitive load by controlling the amount and presentation of information will enhance learners' ability to process that information and transfer it to long-term memory. Information stored in long-term memory can subsequently be recalled to working memory when needed. Sweller (2005) has distinguished three types of cognitive load: intrinsic, germane, and extraneous. *Intrinsic cognitive load* refers to the complexity of the information itself. For example, the Krebs cycle is complex, and learning this cycle in its entirety may require juggling multiple discrete pieces of information simultaneously. There is no good way to decrease intrinsic cognitive load; it is, as the name implies, intrinsic to the problem. *Germane cognitive load* refers to the cognitive resources required by (germane to) the act of learning, as in the process of elaboration described above. Like intrinsic load, germane cognitive load cannot be reduced. *Extraneous cognitive load*, in contrast, arises from anything that taxes cognitive capacities without contributing to the learning process. Extraneous load can come from irrelevant or distracting information (excessive detail), poorly presented information (poorly worded sentences, ambiguous illustrations, or inadequate or excessive structure), the environment (noise or poor lighting), or from within the individual learner (hunger). Because intrinsic, germane, and extraneous cognitive loads are additive, decreasing extraneous load will increase the cognitive capacity available to learn complex material or solve complex problems. Attention to cognitive load may be less important when learning information or solving problems that are inherently easy (low intrinsic load), but with greater complexity cognitive load will quickly become an issue. Cognitive load has particular relevance to e-learning, where issues such as screen design and audio and video fidelity—all of which affect extraneous cognitive load—must be carefully considered in the instructional planning.

Instructional Methods

Instructional methods are activities employed by a teacher to help learners acquire, integrate, and retain new knowledge. Effective instructional methods exemplify the core tenets of learning in practical ways, and several instructional methods were alluded to in the preceding paragraphs. Instructional methods can be broadly grouped as (1) what types of activities will be effective, and (2) the means by which specific activities can be effectively implemented. This section will describe methods that address each of these tasks.

Considering first the effective implementation of specific activities, Mayer (2005) has developed a theory of multimedia learning based largely on cognitive load theory. From this he has derived several practical yet empirically validated principles of instructional design for e-learning (Clark and Mayer 2003; Mayer 2005). For example, the *multimedia principle* suggests that using both words and graphics is more effective than words alone, the *modality principle* advocates using narrated rather than written descriptions of graphics, and the *personalization principle* advises using a conversational tone in composing text. Some principles run counter to common practices, such as the *coherence principle* (unnecessary images or nonessential text will detract from learning), the *worked example principle* (learning improves when some practice problems are replaced with worked examples), and the *expertise-reversal effect* (novice and expert learners have different learning needs). Nonetheless, they are supported by both theory and evidence. These and other principles are summarized in Table 1.

Looking more broadly at what types of activities are effective, Merrill (2002) reviewed theories of instructional design and methods espoused by experts in the field and sought commonalities among the various frameworks. While his synthesis is not supported by evidence per se, most of the principles derived from his review are supported by their own bodies of research. Merrill presumed that "If a principle is included in several instructional design theories, the principle has been found either through experience or empirical research to be valid." He thus identified five "first principles of instruction." The first is that instruction

TABLE 1 SELECTED PRINCIPLES OF MULTIMEDIA LEARNING

Principle	*Learning is . . .*	*Commentary*
Multimedia	Enhanced when both words and graphics are used	Cognitive load decreased by using both textual and pictorial information
Modality	Enhanced when descriptions of graphics are spoken rather than appearing as on-screen text	Cognitive load decreased by using both visual and auditory information
Contiguity	Enhanced when related information (e.g., words and graphics) is placed close together	Extraneous cognitive load decreased by placing information in close proximity
Coherence	Impaired when unnecessary information (pictures, words, sound) is presented	All available information must be processed, even if irrelevant to learning task, thus any extra information unnecessarily increases cognitive load; unnecessary information can also distract from salient details
Personalization	Enhanced when conversational tone is used	Conversational tone invokes lower extraneous cognitive load
Learner pacing	Enhanced when learners control pace of course	Pacing allows learners to adjust speed to maintain ideal levels of cognitive load
Guided discovery	Enhanced when structure (content sequencing, interpretive support) is present	Pure discovery learning (self-directed learning through unguided exploration) imposes high extraneous cognitive load (but note the expertise-reversal effect below)
Worked example	Enhanced when some practice problems are replaced with worked examples	Worked examples decrease cognitive load (but note the expertise-reversal effect below)
Expertise-reversal effect	Enhanced for novice learners when structure and worked examples are provided; enhanced for advanced learners by less structure and unsolved problems	Unstructured instructional designs create unnecessary extraneous cognitive load for novices, whereas structure and worked examples increase cognitive load for advanced learners

Source: See Clark and Mayer (2003) and Mayer (2005) for details and additional principles of multimedia learning.

should be *problem-centered*: "learning is promoted when learners are engaged in solving real world problems." He suggested that each subsequent principle of instruction be implemented in the context of real-world problems. Principle two is *activation*: "learning is promoted when relevant previous experience is activated." By activation, Merrill meant that prior knowledge (information retained in long-term memory) is brought to the forefront (working memory), where it can be acted upon and integrated with new experiences and information. Activation can be promoted when learners are asked to analyze a problem or recall specific experiences, when they are provided with new experiences that relate to past problems, or when they are asked to recall specific structures that can be used to organize new knowledge. Principle three is *demonstration*: "learning is promoted when the instruction demonstrates what is to be learned rather than merely telling [students] information about what is to be learned." Demonstration can consist of providing worked examples (which is particularly useful if contrasting examples are used), pictures, animations, or role modeling. It is helpful to guide novice learners by focusing their attention on relevant information or important parts of a task; as learners advance in training, this guidance should necessarily fade. This principle is in harmony with cognitive load theory: early in instruction learners will be overwhelmed by an overload of information, whereas later in instruction experts will be distracted by unnecessary guidance. Principle four is *application*: "learning is promoted when learners are required to use their new knowledge or skills to solve problems." This is the practice phase, in which learners take the knowledge gained during demonstration and apply it to solving new problems. Again, guidance and coaching should be high at first and then gradually fade. Furthermore, as suggested by Ericsson's principle of distributed, deliberate practice, the type of problems should vary and should be sequenced to promote optimal learning. Principle five is *integration*: "learning is promoted when learners are encouraged to integrate (transfer) the new knowledge or skill into their every day life." Integration can consist of public demonstrations or teaching, reflection, small-group discussion, or use of the information in creative ways.

Some authors have criticized typical instructional designs as failing to adequately represent the real world (Jonassen 1993; Petraglia 1998; Schank 2000; Spiro et al. 1988). These experts argue that instruction should reflect the complexity of real-world problems, for which solutions are frequently not straightforward, and that learners must learn to deal with difficult problems and disparate sources of information rather than avoiding the challenge through simple cases and spoon-fed information. We are concerned, however, that pure "discovery" learning methods, in which learners define objectives and seek answers with little or no advisement, invoke excessive extraneous cognitive load (at least for novices) (Kirschner, Sweller, and Clark 2006; Sweller 2005; van Merriënboer and Sweller 2005). Hence, we concur with Mayer that a degree of structure and some worked examples will enhance learning for novices. Yet the expertise-reversal effect suggests that different methods will be required as learners progress. For example, a course on computer literature searches might employ low-extraneous load methods, such as lectures and worked examples, early on. As the learners' knowledge base grows, progressively higher-load methods could be used, such as using a reference text to solve simple problems and ultimately performing a Medline search to solve complex unknowns.

Instructional Design Models in Web-Based Learning

We conclude our reflection on learning fundamentals by presenting one unified model for instructional design that incorporates all or nearly all of the above principles. This model is the "four-component instructional design" (4C/ID) model developed by van Merriënboer (Janssen-Noordman et al. 2006; van

Merriënboer, Clark, and de Croock 2002). The intent of 4C/ID is to facilitate complex learning while acknowledging the limitations noted by cognitive load theory (van Merriënboer and Sweller 2005). The 4C/ID model involves four distinct components: learning tasks, supportive information, part-task practice, and just-in-time information.

Learning tasks form the backbone of the design process. Learning tasks represent concrete, authentic, whole-task experiences similar to those that would be experienced in real life. These are clustered into groups according to the level of their complexity or difficulty, such that all of the tasks in the same group are of approximately the same difficulty. Within each group, however, there will be wide variation in the specific details of the problem presented. As learners proceed through the course the first task in each grouping has high learner guidance and support—perhaps a fully-worked example. With each subsequent task in a given group (remember that each task within a group is of similar difficulty), the amount of guidance fades, such that by the last task learners are performing independently. They then move on to the next group of tasks, which will be of a slightly greater difficulty. Here again, the first task has learner support, which decreases gradually for subsequent tasks.

Although the learning tasks have some guidance, simply teaching learners to mimic the instructor is insufficient to constitute instruction. Thus, *supportive information* is provided in the form of theory and other content information. The goal of supportive information is to build mental models and strategies for problem solving within each specific domain.

At various stages along the way, task elements will arise that are predominantly repetitive. For example, when diagnosing osteoporosis an essential subtask is interpreting the dual-energy X-ray absorptiometry (DEXA) scan (a radiographic measurement of bone density). Such repetitive subtasks can be perfected through the use of *part-task practice*. Here, multiple brief instances of the particular subtask (for example, a DEXA scan report) are presented to the learner in succession so that she can develop expertise. This is similar to learning times tables until multiplication becomes automatic: once it is learned, one invests virtually no mental energy to know that $7 \times 8 = 56$. In like manner, part-task practice helps specific subtasks within the complex task become automatic and thus reduces the cognitive load necessary to carry these out.

Just-in-time information is the information needed to complete a part-task practice subtask. For a student learning to multiply, it would be the products arranged in multiplication tables. For DEXA scan interpretation, it might be a diagram that highlights the location of key information in the DEXA scan report, or an interpretive rubric describing WHO criteria for osteoporosis. This just-in-time information is available as needed throughout the part-task practice (and indeed throughout all learning tasks), but the objective is that as subtasks become automatic there will be progressively less reliance upon the just-in-time information.

Thus, the learner begins with whole learning tasks that are relatively easy (but nonetheless representative of real life), and progresses over time and with additional supportive information and part-task practice to the point that he or she is able to deal with exceedingly complex problems. This learning environment lends itself to e-learning where different components can be easily accessed by clicking a mouse. However, the 4C/ID model is not restricted to e-learning: indeed, the same design principles could be used to develop a course in communication skills, surgical techniques, or advanced cardiac life support in more traditional settings (Janssen-Noordman et al. 2006).

Roles and Issues for Specific E-Learning Modalities

E-learning comes in many different forms and configurations, ranging from highly structured tutorials to free-text online searches. Often one course will incorporate several different configurations, for example, starting with a tutorial, then using a virtual patient for practice, prescribing a homework assignment using the Internet as an information source, and then using e-mail or point-of-care (just-in-time) reminders to reinforce learning. Each of these configurations (and of course the many others not listed here) has specific advantages and disadvantages, particular challenges and potential pitfalls in instructional design, and a great number of unknowns that beg future research. In the remainder of this article we discuss five specific configurations and present an overview of some of these issues. In practice, the distinction between these different modalities is often blurred.

Tutorials

Online tutorials are similar to face-to-face lectures. They consist of structured information, often enhanced by multimedia and hyperlinked online resources. They typically incorporate elements to enhance interactivity, such as self-assessment questions, patient cases, objects for manipulation, or games.

Some educators view lectures (and e-learning tutorials) as an inferior method of teaching. However, this reputation is ill deserved. True, some lectures (and tutorials) are indeed of poor instructional quality—but they need not be so. Well-designed lectures (and tutorials) incorporating the principles discussed above can be very effective, particularly when the objective is to learn core knowledge (Brown and Manogue 2001). Learners must create their own knowledge structures by integrating new information with their prior knowledge (Dewey 1998), and well-structured lectures and tutorials can greatly facilitate this process.

There are several challenges in the use of online tutorials. Perhaps the most pervasive is poor instructional design. As alluded to above, the quality of instructional design varies widely. Simply converting lecture notes or a monograph to an e-learning format will not effectively facilitate learning (Cook and Dupras 2004). Rather, instruction should be carefully designed—using principles described above and other evidence-based principles—to effectively communicate the desired information. Note that the specific instructional methods employed will vary according to the content domain and the desired learning outcomes. Another concern with tutorials is the difficulty in adapting instruction to the needs of individual learners (Chen and Paul 2003). Most tutorials are fixed (as are most lectures) and may not match the level of knowledge (too high or too low) or the optimal learning strategies for a given learner. Some concerns have been raised regarding social isolation: if learners exclusively use online tutorials, will their social interactions with fellow students suffer? The cost of tutorials is another challenge: while creating a simple Web page is easy and inexpensive, developing a well-designed online tutorial can be very expensive.

Research in this field should address questions related to the above issues and many others. For example, how can e-learning tutorials be individualized? (Cook 2005b; Park and Lee 2004). Is computer-directed adaptation, in which the computer assesses a learner characteristic (such as existing knowledge or cognitive style) and alters the presentation accordingly, effective (Cook 2005a; Kohlmeier et al. 2003])? If so, what learner characteristic(s) permit useful adaptation? Is it better to allow learners to select from among various options in a Web-based course? In discussing instructional design, research should elucidate what instructional methods are most effective for specific learning outcomes, and also how to effectively use multimedia and other resources. If effective instructional design can be identified, automation of course development could reduce development costs while maintaining high standards of quality (Spector and Ohrazda 2004).

Virtual Patients

Virtual patients are computer-based simulations of patient encounters. Learners typically obtain information about history, exam, and ancillary tests in a sequential unfolding, often by interrogating the computer. They are typically asked along the way to interpret specific elements of the history, exam, and test results, and to arrive at a diagnosis or implement therapy. In contrast to online tutorials, which are most effective in facilitating development of core knowledge, we believe virtual patients are most useful in the development of clinical reasoning. As discussed in the previous section, clinical reasoning appears to be best developed through distributed, deliberate practice. Virtual patients can provide "experiences," and the computer can act as a coach in directing attention, suggesting strategies, and providing feedback.

As with online tutorials, however, there are many challenges in the development and implementation of virtual patients. Not the least of these is variation in the quality of the virtual patient. Learners must be stimulated to become cognitively engaged in the case, but this can often be difficult to achieve. The computer infrastructure (software) for presenting virtual patients effectively can be very difficult and expensive to develop. Several universities and for-profit corporations have developed flexible software, yet the development of case scripts is still difficult. MedBiquitous is working to develop a standardized nomenclature by which cases can be shared among educators and institutions (MedBiquitous Consortium 2007). Another challenge is integration of virtual patients into the curriculum; it is not infrequent for virtual patients to be underutilized after great investment into their development.

Little research in this field has been published, leaving many questions unanswered. What are the elements of effective case design (and how do these vary for learners at different training levels)? Should learners be presented information, or should they interrogate the computer? When interrogating the computer, should they use pre-scripted questions or free-text queries? (Some research suggests that free-text queries may increase cognitive load if the computer has even minor difficulties interpreting the question [Bryce et al. 1998]). What is the appropriate level of fidelity in the patient—are low-quality pictures or illustrations adequate, or are high-quality photographs, video clips, and animations required (Alessi 1988)? How can virtual patients be effectively integrated into the curriculum? Should cases be completed alone or as a group? Finally, can the learner's path through the virtual patient (the questions asked, diagnoses entertained, etc.) be effectively used as an assessment?

Online Resources

As more information is widely available on the Internet, the use of available online resources must be considered as a learning modality. Research has documented the utility of Google in solving difficult to diagnostic dilemmas, and other research suggests that increased use of *UpToDate* may increase residents' in-training exam scores (McDonald, Zeger, and Kolars 2007; Tang and Ng 2006). Learning with online resources seems ideal in the clinical setting when learners are faced with specific cases for which they identify knowledge deficits. At this point, they are primed for learning, and information is more likely to be retained.

While online resources have great potential, there are challenges. First and foremost, simply making resources available does not guarantee their use, and in particular, does not guarantee that they will be used effectively (D'Alessandro, Kreiter, and Peterson 2004). Such resources can of course be used ad hoc to answer specific clinical questions. However, does this count as "instruction" without structure, supervision, feedback, or monitoring of use? Online resources also open the door to cognitive overload, particularly for novice learners (Clark 2005). This is one form of discovery learning and has the associated dangers. Furthermore, the selection of resources is important: while much useful information is available on the Internet, much misinformation is also found. Finally while the information obtained may be helpful in solving one case, the degree to which this information will transfer to a new case is unknown.

Research will be a natural outgrowth of these challenges. We must explore how to utilize these resources effectively while minimizing cognitive overload.

In settings that lend themselves to organized approaches, it will be important to develop appropriate triggers to stimulate learning, monitor the use of online resources, and facilitate the integration of this information in a way that will transfer to future patients.

Just-in-Time Learning

Just-in-time learning (not to be confused with the just-in-time information component of the 4C/ID model) involves the delivery of educational information at critical stages in a clinical encounter. While this modality could be used at any point in the training continuum, its most distinctive niche may be in reaching those at more advanced training levels, such as those in postgraduate training or already in practice. Thus far, most interventions with just-in-time learning have taken the form of clinical decision support tools (Chaudhry et al. 2006). Interventions specifically designed with education in mind are now being studied as well (Leung et al. 2003).

Perhaps the greatest challenge when using just-in-time learning is the absence of structure and reinforcement. While these aids certainly facilitate immediate decision making, it is unclear what happens when the support is no longer present. Will this information be integrated into useable memory structures, or will the information be scattered such that it cannot be recalled at relevant times? An additional challenge is the time it takes to read, digest, and assimilate this information in a hectic clinical schedule. Learners (who could be practicing clinicians) may resent this if it is thrust upon them (for example, as mandatory pop-ups or unsolicited e-mail reminders). Furthermore, there are issues related to the development of these systems, such as how to trigger the information, how much information to present, and how to organize and update the information.

Research in this area should again be a natural outgrowth of these challenges, addressing issues such as how much information to present, how to organize or structure this information in a way that leads to meaningful learning, how to ensure actual learning rather than mechanical incorporation of guidelines, and how to motivate learning.

E-Learning Discussion

E-learning discussions are similar to face-to-face small group sessions. Although there may be some didactic teaching, for the most part the teacher is a facilitator and the discussion amongst class members constitutes the real instruction. Discussions can contribute to virtually any learning setting but may be particularly useful in facilitating critical thinking and reflection.

One of the greatest challenges in online discussion groups is motivating the learners to participate (Sargeant et al. 2000). If participation drops off, the course will quickly flounder (Steinert et al. 2002). Furthermore, e-learning discussions frequently consist predominantly of superficial comments and social conversations that fail to stimulate deep cognitive engagement (Tallent-Runnels et al.

2006). Another significant concern is the amount of instructor time involved in monitoring and facilitating discussions. In contrast to most of the other e-learning modalities mentioned above, in which additional learners can be easily accommodated with little or no increased cost, each additional learner in an online discussion group creates new demands on faculty (Nathoo, Goldhoff, and Quattrochi 2005; Weir et al. 2004). As with all e-learning interventions, instructional design is a critical consideration. Finally, there have been concerns about how online social interactions will translate to real-world settings. For example, will team dynamics be affected by shifting to online rather than face-to-face communication?

Once again, multiple research issues derive from these challenges. How can learners be motivated to participate in e-learning discussions? How can instructor time best be used, and are there alternatives to using full-time faculty instructors as facilitators? How can instructional design in discussion groups be optimized, and what effects do discussion groups have on team dynamics and other communication skills?

General Issues

There are other general issues relevant to e-learning. Perhaps the most important of these is that e-learning be used in appropriate situations. All too frequently, educators and administrators seek to use e-learning because it is a new technology, rather than because this technology will enhance instructional activities. For example, we know of online discussion groups for learners who meet face-to-face at other times during the day, online tutorials replacing lectures, virtual patients taking the place of standardized patients or real patients, and so on. While we do not make any global judgments regarding whether e-learning is appropriate in any of these situations, we again emphasize that there is nothing magical about e-learning. It is unlikely to improve upon instruction that is already excellent and appropriate, and it could potentially make some learning situations worse. We reiterate the critical need to consider the learning goals and objectives and then determine whether e-learning could contribute; and if so, what modality or combination of modalities would be most appropriate.

Conclusion

E-learning is here to stay. Although we strongly doubt that it will ever replace face-to-face learning, if recent trends are any indication e-learning is going to increase in medical education over the next several years. We anticipate with great interest what the future will bring. Twenty years ago, the Internet could scarcely be imagined; today it is a ubiquitous and pervasive influence in our lives. The next 20 years are likely to see even more powerful technologies arise that will dwarf our current conceptions of e-learning. Already we see technologies such as mobile computing (handhelds) enhancing point-of-care instruction, online communities such as blogs and wikis forming a nidus for group instruction, and web feed formats such as RSS facilitating frequent updates in areas of user interest (Giustini 2006).

Yet, concomitant with our excitement for how future technologies may augment medical education, we wish to issue a cautionary note regarding overenthusiasm about each new wave of technology. Educators must remember that technology is a tool, not an end in itself. E-learning and its successors, as much as it predecessors, will only be useful inasmuch as teachers keep foremost in mind the needs of the learners, the desired learning objectives and outcomes, and the match between instructional methods/design and those needs and objectives. Educators should resist the temptation to use technology for technology's sake and instead use these tools judiciously to enhance training. E-learning may or may not revolutionize medical education, but the ultimate goal—a competent and compassionate physician—will remain unchanged.

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