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Distributed Learning System Design: A New Approach and an Agenda for Future Research

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Abstract

This article presents a theoretical framework designed to guide distributed learning design, with the goal of enhancing the effectiveness of distributed learning systems. The authors begin with a review of the extant research on distributed learning design, and themes embedded in this literature are extracted and discussed to identify critical gaps that should be addressed by future work in this area. A conceptual framework that integrates instructional objectives, targeted competencies, instructional design considerations, and technological features is then developed to address the most pressing gaps in current research and practice. The rationale and logic underlying this framework is explicated. The framework is designed to help guide trainers and instructional designers through critical stages of the distributed learning system design process. In addition, it is intended to help researchers identify critical issues that should serve as the focus of future research efforts. Recommendations and future research directions are presented and discussed.

Distributed Learning System Design: A New Approach and an Agenda for Future Research

Over the past decade, there has been steady growth in the utilization of distance learning and distributed training by both private and public organizations (Salas & Cannon-Bowers, 2001). Recent estimates suggest that nearly 80 percent of all companies are using some form of distributed, computer-based training (Kiser, 2001). Many companies have also increased their emphasis on distributed learning since September 11, 2001 (Van Buren & Erskine, 2002), and technological advances, business trends (e.g., increased globalization), and educational trends (e.g., virtual universities) lead most experts to predict that over the next few years organizations will increasingly shift their attention and resources from more traditional training courses (e.g., classroom instruction) to technology-based training programs (e.g., web-based training). The Internet-based learning market alone is projected to grow to $46 billion this year (Peterson, Marostica, & Callahan, 1999).

The recent growth in the use of distance learning and distributed training, what we refer to collectively as *distributed learning systems* (DLS), has been stimulated largely by the practical benefits associated with developing learning environments that transcend space and time (Welsh, Wanberg, Brown, & Simmering, 2003). A substantial portion of training costs—upwards of 80%—is devoted to simply getting trainees to the training site, maintaining them while there, and absorbing their lost productivity (Kozlowski, Toney, Mullins, Weissbein, Brown, & Bell, 2001). However, by creating training systems that allow learning to occur almost anywhere and at anytime organizations can avoid these costs, which is particularly attractive to decentralized organizations with geographically dispersed employees (Hawkridge, 2000; Welsh, 1993). In educational settings, DLS allow universities to reduce instructor and facilities expenses, by reusing course content for example, and enable them to tap into a larger student market. In addition, electronic learning applications are extremely flexible; content can be updated quickly and trainees often have the ability to structure their own learning experience.

This flexibility allows organizations to create adaptive, just-in-time training programs that, in turn, enhance their ability to respond more quickly and effectively to employees' and students' learning needs.

Whereas distributed learning was once limited by relatively simple, asynchronous technologies (e.g., one-way video and voice communication), recent advances have led to the development of more sophisticated, reliable, and cost-efficient technologies (Noe, 1999). Current DLS technologies can be thought of as points along a technology continuum, which ranges from low-technology (e.g., video) to highly complex and interactive technologies (e.g., virtual reality; Salas, Kosarzycki, Burke, Fiore, & Stone, 2002). As the scope of DLS technologies has expanded, a great deal of attention has been focused on how to harness their potential in the development of more powerful, faster, and less expensive systems. Indeed, the literature on distance learning and distributed training, both popular and academic, has been dominated by discussions concerning technological innovations and issues.

One negative side effect of the heavy emphasis on technology is that both researchers and practitioners have paid far less attention to critical instructional design issues surrounding distributed learning. The purpose of such systems is to promote *learning*, yet the tendency is to design distributed learning around the media and supporting technologies rather than the underlying instructional goals and objectives of the training. This is not surprising given that there is currently no well developed theoretical framework or model to guide training design in distributed environments. However, for instructional strategies to be optimally effective, trainers and instructional designers must integrate learning models with instructional design practices. It is critical, therefore, to develop theory that can be used to guide DLS design. In the absence of such theory, many organizations have discovered that their distributed learning systems, while practical and cost-efficient, are suboptimal or even ineffective for developing critical knowledge and skills. As Hamid (2002) notes, the growing consensus is that "after the initial excitement, many e-learning initiatives have fallen short of expectations" (p. 312).

The purpose of this article is twofold. First, we provide a focused review of the current literature on DLS design. In particular, we argue that two issues – technology and effectiveness – have consumed much of the attention in the literature on distributed learning system design. Our goal is not to provide a comprehensive analysis of the literature on DLS design, but rather to generate insight into the issues that are currently driving research and practice in this area. A critical conclusion derived from this review is that this body of work is largely pragmatic and lacks the necessary conceptual foundation for generating scientific principles to guide DLS design. Thus, our second goal is to present an integrated model that outlines a theoretically-based approach to distributed learning design. We highlight the key elements of this model and propose an agenda that can help guide future research in this area and lead to the foundation of knowledge necessary to implement the proposed approach to DLS design. Ultimately, our purpose is to highlight the instructional design and pedagogical issues surrounding DLS design that we believe future research must address in order to develop the conceptual foundation necessary to guide future practice in this area.

Current DLS Research

As a first step in developing our model, we conducted a review of the current literature on distributed learning system design. Our review focused on not only distributed learning, but also relevant topics in related areas such as remote collaboration and computer-mediated communication. The review revealed that most decisions in the design process, ranging from the initial decision to utilize technology in training delivery to the actual design and delivery of the training program, are driven by a focus on two interrelated factors: technology and effectiveness. In the following sections we discuss these two topics in more detail.

Technology

For a number of years, distributed learning was limited to relatively basic computer-based text programs or video-based instruction. However, recent technological advances have expanded greatly the breadth and depth of DLS technologies. Several of the more advanced technologies currently being used by organizations include: interactive media, web-based training, and virtual reality. As the media, connectivity, and bandwidth (e.g., compressed video; PCs, Internet; broadband) that support these advanced technologies have become more cost-efficient and reliable, organizations have increasingly utilized an array of more advanced and complex distributed learning technologies.

Table 1 catalogues the broad range of technologies that have the potential to be used in distributed learning and describes typical applications and examples. At the lower end of the technology continuum are CD-ROM and DVD, which offer the capability to integrate text, graphics, animation, audio, and video into a multimedia presentation. One advantage of CD-ROM and DVD over more traditional videotape programs is that the computer-based delivery makes it possible to create programs in which trainees interact with content using a keyboard, mouse, or touchpad. Whereas video requires a linear progression through instructional material, CD and DVD can provide learners with greater control over the sequence of instruction through independent navigation and branching features (e.g., hyperlinks). Another widely used technology is web-based training. There is tremendous variability in web-based training programs; some simply represent computer-based delivery of text while others integrate multimedia, hyperlinks to references, communication systems, and assessment tools into a high-tech instructional experience. Finally, at the high-end of the technology continuum there is virtual reality systems, which can offer a high degree of psychological and contextual fidelity by immersing trainees in a realistic performance environment.

Considerable research attention has been focused on classifying the component technologies and media available to support distributed learning. The frameworks that have emerged from such efforts typically distinguish DLS technologies on one or more dimensions, including the level/complexity of the technology (low vs. high), time (synchronous vs. asynchronous), and information richness (low vs. high). While such frameworks are useful for

Table 1
Distributed Learning System Technologies

System	*Primary Features*	Examples
CD-ROM DVD	• Integrates text, graphics, animation, audio, and video. • Computer-based delivery provides trainees with an opportunity to interact with content and greater control over sequence of learning.	• Colorado State University utilizes DVDs and CD-ROMs in its Continuing Education program to provide students with an opportunity to obtain distance degrees. • The United Way uses CD-ROMs to provide staff and volunteers with information on the history, philosophy, and business of the United Way system.
Interactive Video	• Instruction is broadcast either live or via videotape and trainees can use a keyboard, interactive monitor, or touchpad to interact with the program. • Live instruction may also incorporate communication systems.	• Ford Motor Company's Dealer Communications Network is used to broadcast over 70 hours of instruction per day to their worldwide dealership network. The system offers interactive conversation and trainees use a touchpad to input responses to questions, which are then tabulated by the system.
Web-based Training	• Can allow communication between trainers and trainees and among trainees. • On-line referencing. • Testing assessment. • Delivery of multimedia. • Hyperlinks allow trainees to control sequencing of instruction.	• FedEx has created a custom leadership development tool, called Developing High Performers, that is entirely web-based. The tool includes both assessments and development activities, such as management simulations. • NASA and the State of Florida collaborated to develop the Advanced Learning Environment, an entirely web-based virtual learning and collaboration community, to train the next generation of aerospace workers.
Intelligent Tutoring Systems	• Artificial intelligence used to provide trainees with individualized instruction and guidance. • Trainee performance is analyzed to provide feedback and coaching and also to generate future scenarios and instruction.	• The Cognitive Tutor Algebra course developed at Carnegie Mellon University uses detailed computational models to provide students with individualized guidance as they work on challenging, real-world problems.
Electronic Performance Support Systems	• Computer applications that provide skills training, information access, or expert advice upon request. • Often used as an employee assistance device, but can also be used as a training tool.	• Payless ShoeSource Inc. uses a just-in-time support system to train workers on the job and to collect and share best practices. The interface resembles an actual store layout and users click on icons to learn about topics such as customer service and inventory management.
Virtual Reality	• Provides trainees with a three-dimensional learning experience. • Trainees move through the simulated environment and interact with its components. • Trainees in different locations can be linked in a simulated environment.	• Researchers at the University of Missouri-Rolla are developing a virtual reality program to train first responders how to react to terrorist events. Users wear headgear with goggles and ear pieces as well as all their normal equipment, and practice responding to simulated events in the virtual reality environment.

understanding the range of technologies available to support DLS, they have often been inappropriately used to guide technology selection and distributed learning design. Often overlooked is the fact that the suitability of a particular DLS technology is dependent on the nature of the instructional situation. What is lacking is a framework that links technologies, and their specific attributes and properties, to specific instructional goals and outcomes.

To date, very little research has attempted to evaluate distributed learning technologies in terms of their ability to create specific learning experiences and develop different types of knowledge and skills. Although a few efforts have been undertaken to analyze the instructional properties of different distributed learning technologies (see Clark & Mayer, 2002; Schreiber, 1998 for examples), most research has focused on application issues. For example, one issue that has received attention involves the creation and adoption of technical standards and requirements that will promote content reusability, accessibility, durability, and interoperability (e.g., Smith & Diamond, 2000). Other topics that have attracted attention include the development of reusable electronic learning objects (e.g., Muzio, Heins, & Mundell, 2002), issues surrounding the usability of different technologies (e.g., Parlengeli, Marchigiani, & Bagnara, 1999), and the development of technological systems that support virtual, collaborative learning environments (e.g., Bouras, Philopoulos, & Tsiatsos, 2001; Collis & Smith, 1997).

Effectiveness

A second issue that has garnered considerable attention in the literature on distributed learning design is that of effectiveness. Initially, this research focused on comparing the effectiveness of distributed learning to more traditional instructional techniques, typically classroom-based lecture. More recently, research has focused attention on investigating factors that may influence distributed learning effectiveness, including media issues and characteristics of the learning environment. Although the evaluation criteria utilized in these studies have been numerous, considerable attention has been devoted to practical concerns. More specifically, the focus of much of this research has been on how to design distributed learning so as to achieve learning outcomes equivalent to traditional training, while at the same time maximizing financial and practical (e.g., reduction in training time) benefits. Prominent themes in the research on the effectiveness of distributed learning are briefly reviewed below.

***Comparison to traditional training**.* A large number of studies have compared the effectiveness of DLS to more traditional instruction. The outcomes on which such comparisons have been based are diverse, but the most common include performance, cost, and time. Although a few studies have revealed significant performance differences (e.g., Faux & Black-Hughes, 2000; Ortiz, 1994; Wisher & Priest, 1998), the vast majority of studies have found no significant differences in the performance achieved using distributed learning and traditional instruction (e.g., Huff, 2000; Petracchi & Patchner, 2001; Williams & Zahed, 1996; Wisher & Curnow, 1999). In terms of cost, most studies have found that distributed learning costs less than traditional training. Wisher and Priest (1998), for example, found that using teletraining for the Army National Guard Unit Clerk Course would save $292,000 a year. In large organizations with many training programs, these cost savings can add up to millions of dollars annually (Welsh et al., 2003). However, it is important to recognize that such savings can only be realized *after* the costs of the technology infrastructure are considered. That is, because of the significant startup costs (e.g., purchasing hardware, software, instructional design, etc.) involved in developing DLS, cost savings are typically achieved only when a program is administered repeatedly or for a significantly large number of students. Phelps, Wells, Ashworth, and Hahn (1991), for example, found that using asynchronous computer conferencing for an Army reservist engineering course cost 43% less than a resident course after five iterations. Finally, several studies have compared distributed learning and traditional training with respect to total training time. Research suggests that putting a training program on-line can reduce total training time by a quarter to a third (Kulik & Kulik, 1993; Winkler, Moody, & Kahan, 1993).

Although most studies evaluate the effectiveness of distributed learning on the basis of some combination of performance, cost, and time, other outcomes have also been considered. For example, some work has addressed issues of diversity and access. Some argue that on-line learning can increase collaboration among individuals with diverse backgrounds by leveling social barriers (e.g., Ancis, 1998). Technology can be used to facilitate collaborative learning among individuals drawn from different ethnic, cultural, racial, gender, and socio-economic backgrounds. Finally, the flexibility offered by distributed learning may provide increased access to individuals who otherwise may be unable to attend training or classes, such as individuals with disabilities (Salas et al., 2002).

Media issues*.* A second theme that has emerged in the literature on the effectiveness of DLS concerns the relationship between delivery media and effectiveness. Much of this research has focused on the return on investment (ROI) associated with different types of distributed learning media (e.g., Alterkruse & Brew, 2000; Wisher & Priest, 1998). Issues that have been examined with respect to specific media include initial startup costs, operating costs, and the costs associated with upgrading content. Given that many organizations implement distributed learning systems for economic reasons, there is a great deal of interest in this topic.

A number of studies have also examined the effectiveness of different delivery media or technologies. For example, Wisher and Curnow (1997) examined whether transmitting an image of the instructor in a distance learning course influenced student reactions and learning. They found that although some students reported that the instructor image helped them learn, it made no difference in terms of actual learning. Similarly, Lee, Liang, & Chan (1999) compared the effectiveness of three synchronous, collaborative learning systems, a co-working system, a working along system, and a hybrid system, and Guzley, Avanzino, & Bor (2001) explored student perceptions (e.g., satisfaction, perceived effectiveness) of a two-way synchronous audio/visual learning technology. Other studies have examined whether embedding support systems, such as listservs or bulletin boards, in DLS influences trainee reactions and learning

(Johnson & Huff, 2000). Finally, a few studies have examined the relationship between the "quality" of technology and training effectiveness. For example, several studies have shown that technology reliability has a positive impact on trainees' reactions and perceived training effectiveness (e.g., Cavanaugh, Milkovich, & Tang, 2000; Webster & Hackley, 1997). One issue to note is that while each of these studies adds to our understanding of the impact of media factors on effectiveness in some small way, the research is ad hoc; it is not systematic.

Contextual characteristics. Another issue that has received considerable attention is the effect of the learning context on DLS effectiveness. It is important to note that this theme is most prevalent in the literature on distance learning where individuals often gather in classroom-like environments at remote learning sites. Numerous studies have investigated the impact of site characteristics on the effectiveness of distance learning programs. Biner, Welsh, Barone, Summers, and Dean (1997), for example, examined the effect of site size on students' reactions to and performance in a distance learning course. They found that site size was negatively related to course satisfaction and performance. In fact, students who participated alone at sites exhibited the highest levels of satisfaction and performance.

There is considerable debate in the distributed training and distance learning literatures about whether contextual characteristics are important. On the one side, some argue that group atmosphere, interactions among students and between students and teachers, and sense of community offered by traditional, face-to-face instruction are critical for learning (e.g., Farber, 1998; Webster & Hackley, 1997). Rovai (2002), for example, surveyed students in 26 graduate-level, distance learning courses and found a significant and positive relationship between learners' sense of community and their perceived cognitive learning. However, other research, such as the study by Biner et al. (1999) discussed above, suggests that a sense of community or group interaction may be relatively unimportant. Falling between these two camps are studies that argue that feelings of connectedness and community are important, but they can be created through particular technologies, such as listservs, email, and bulletin-boards (e.g., Johnson &

Huff, 2000), or by adopting a blended approach in which distributed learning is supplemented by face-to-face group activities (Boling & Robinson, 1999).

It is likely that each of the positions detailed above is likely to hold true in particular learning situations. We assert that the importance of the learning context depends on the nature of the training and the extent to which different types of interaction (e.g., student-student, instructor-student) are critical to developing the desired knowledge and skills. In other words, we believe that research which incorporates the contingencies relevant to specific instructional goals and learning mechanisms will need to be conducted before one can draw firm conclusions regarding the importance of contextual characteristics, such as collaboration and group interaction, for DLS effectiveness. Universals are likely to be lacking.

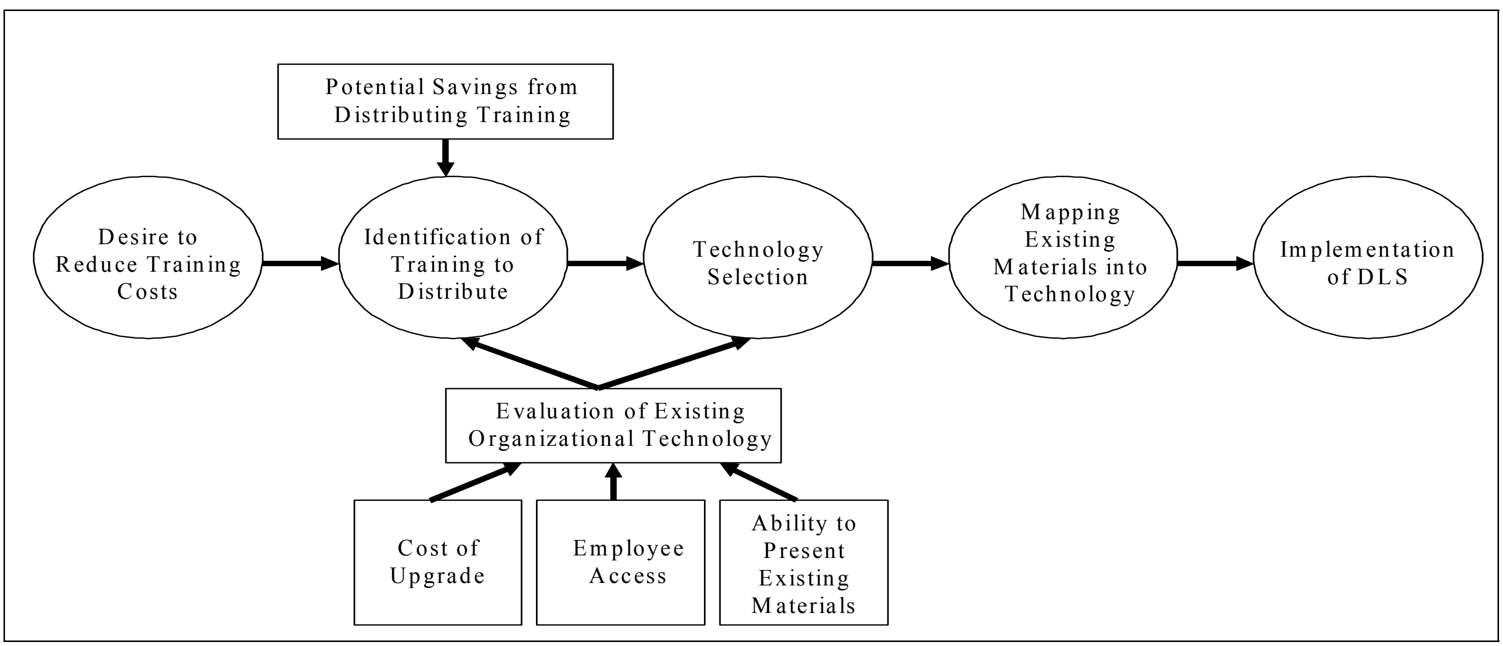
Distributed Learning System Design

Current DLS Design

As detailed above, research on DLS design is characterized by two main themes — technology and effectiveness. Indeed, much of the research in this area has been driven by researchers' preoccupation with the relationship between these two issues. That is, a search for technologies that will lead to the same level of instructional effectiveness as conventional classroom training, but at a lower cost. It is for this reason that the field has not merely accepted—it has embraced—the robust finding that distributed training generally produces no significant differences in learning while costing less than traditional training. Without question, the potential financial and practical benefits of distributed learning are very attractive. At the same time, however, many important instructional issues surrounding distributed learning have been neglected as a result of the heavy emphasis that has been placed on these pragmatic concerns.

The logic of current distributed learning design is illustrated in Figure 1. As shown in the figure, the availability of technology and cost factors are the primary considerations driving the selection of the technological platform. Instructional issues typically receive very little, if any, attention during this selection process. It has been noted, for instance, that learning technology vendors often purposely distance themselves from pedagogical issues (Govindasamy, 2002). The figure also shows that rather than focusing on creating an appropriate technology-content fit, existing content is often simply mapped onto the technology, a practice known as "repurposing." Due to the lack of attention to instructional issues during the design process, the development of desired knowledge and skills is more a matter of chance than intent. Frequently, however, this design process will yield training that is ineffective because the technological environment does not deliver the instructional experience necessary for imparting desired competencies (Govindasamy, 2002). Alternatively, the technology-driven logic outlined in Figure 1 might yield training that is effective but inefficient because more is invested in technology than is necessary to achieve desired instructional goals. In either case, the end result is less than optimal.

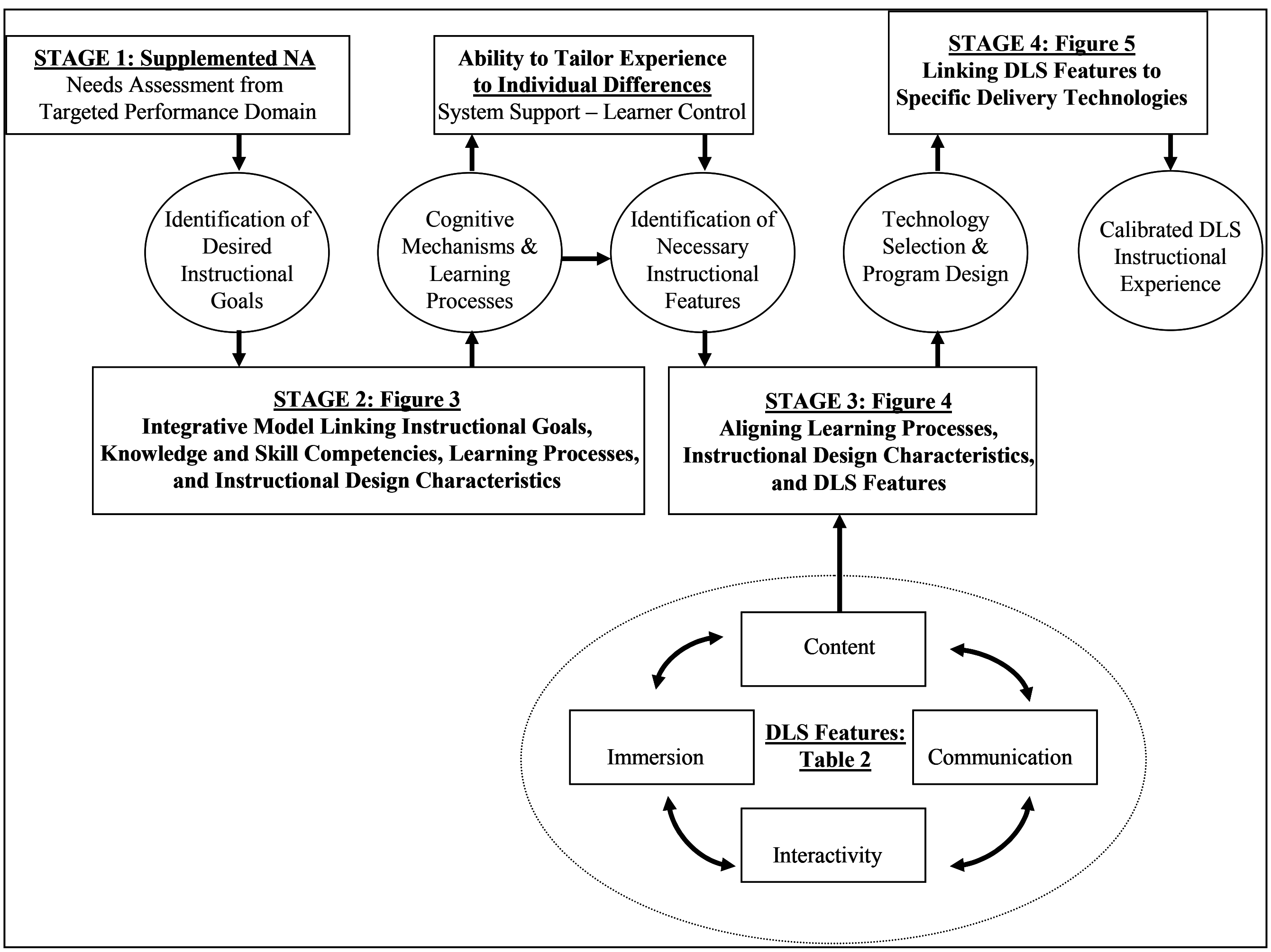
Figure 1. Conventional Distributed Training Design Process



A Theoretical Approach

We assert that to maximize both the effectiveness and efficiency of DLS, the design process must be driven by instructional design principles, not technologies. A heuristic illustrating this proposed logic is shown in Figure 2. As with traditional instructional system design, the figure outlines a series of stages that define the DLS design process. However, the discrete stages are supplemented with conceptual models that provide the theoretical underpinnings. The first stage involves identifying the desired instructional goals. That is, determining the knowledge and skill competencies being targeted by the training program. Different instructional goals implicate particular cognitive mechanisms and learning processes.

Figure 2
A theoretically-based, Integrated Approach to Distributed Learning System (DLS) Design



Thus, the second stage in the design process is identifying the psychological mechanisms that underlie the development of the targeted competencies. Once these mechanisms have been identified, it is then possible to focus attention on the design of the instructional environment. The third stage in our model, therefore, involves identifying the instructional features necessary to stimulate and support the critical learning processes. Up to this point, the stages that have been outlined follow a sequence much like that in traditional instructional design models. It is not until late in the design process that technology issues are considered. Technology selection is appropriately placed at the end point of the design process, because technology should be viewed as tool for ensuring the delivery of an instructional experience that is aligned with training needs and instructional targets. Thus, in the fourth stage of our model, appropriate instructional delivery technologies are selected and combined to create the DLS. The end result of this theory-driven instructional design process is a calibrated DLS that delivers a cost efficient and effective training experience.

By focusing so much attention on practical issues, the potential for using DLS to *enhance* learning and performance, rather than simply replicating the status quo, has often been overlooked. The approach illustrated in Figure 2 and outlined above has the potential to offer a solution that balances both instructional and practical objectives. The challenge in implementing this new approach, however, is that the field hasn't constructed the research foundation for the linkages and core elements specified in Figure 2. What are the important issues to consider when conducting needs assessment in the DLS context? How can different technology features be used to create different types of learning experiences? How do the technology features map onto different delivery technologies? To begin addressing these questions, it is necessary to supplement the traditional instructional design stage logic with theory that takes into consideration the unique elements of designing virtual learning systems. Thus, the stages in our design model are supported by conceptual frameworks. These frameworks address critical issues and decision-making points at each stage of the DLS design process and, as shown in Figure 2, link together the different stages of the design process. In the short term these frameworks guide distributed training design, and in the long-term they can stimulate a systematic research agenda focused on elaborating a comprehensive theory of DLS design. In the following sections, we provide a closer examination of the core stages in the proposed design process and elaborate the supporting conceptual frameworks.

Stage 1: Identification of Desired Instructional Goals

There is no disagreement among researchers that an assessment of training needs is of utmost importance in developing a systematic approach to training (Goldstein & Ford, 2002; McGehee & Thayer, 1961), and the design of distributed training is no exception. A needs assessment serves as the starting point in DLS design process because it clarifies the goals of the instruction and highlights the role of various person and contextual factors in shaping learning in virtual environments.

The first step of the training needs assessment process is typically an analysis of the organization; its objectives, its resources, and the allocation of those resources to training and development activities. As with traditional training design, organization analysis when conducted in the context of distributed learning should consider issues such as whether to make or buy the training, whether the organization has the resources (e.g., time, money) to commit to the training, and whether there is sufficient buy-in among managers and employees. However, some unique issues arise in distributed learning environments. For instance, it will be important to consider whether distributed learning is consistent with the organization's culture (DeRouin, Fritzsche, & Salas, 2004). In organizations that emphasize a "high touch" culture, distributed training may be viewed as taking away valuable opportunities for networking with other employees and management. Also, organizations must evaluate whether the technology infrastructure necessary to conduct the training is in place. If improvements are necessary, does the organization have the resources available to achieve the desired technological capability? These resource decisions must be guided by a firm understanding of the capability of various technologies to successfully achieve different types of instructional objectives, an issue we examine in more detail later.

Paramount to developing an instructionally sound approach to DLS design is focusing greater attention on the learning outcomes targeted by instruction. Identification of instructional objectives occurs during the task analysis stage of the needs assessment process. Task analysis determines the activities performed on the job, the knowledge and skills needed to perform, and the conditions under which the job is done. The result is a detailed understanding of the competencies necessary for successful performance, and those competencies become potential targets of instruction. In Figure 3 we present an integrative framework aligning instructional goals, knowledge and skill competencies, learning processes, and instructional design characteristics. The bottom half of this framework will be discussed in more detail below, but at this point it is important to highlight the instructional goals that form the foundation of the framework. These goals are sequenced from basic to advanced knowledge and skill complexity, which is consistent with contemporary theories of learning that argue for the progressive development of knowledge and skill competencies (Anderson, 1982). At the most basic level there is declarative knowledge, which is knowledge of important facts, concepts, and rules that define the domain. Through practice and experience, declarative knowledge becomes proceduralized, which means that information about situations, responses, and outcomes is integrated to form context-specific rules for application (Ford & Kraiger, 1995; Ohlsson, 1987). Procedural knowledge represents an understanding of conditions and actions that guide the application of one's knowledge. As individuals practice applying their knowledge and skills in a variety of situations, they integrate contextual knowledge into their mental model of a domain. They become aware of the consequences of their actions and changes in context, and begin to see the big picture (Dubois, 2002). This allows them to develop strategic knowledge and skills, which involves an understanding of the contingencies that drive shifts in prioritization and the allocation of attention and effort (Bell & Kozlowski, 2002a).

Figure 3
An Integrative Model Aligning Instructional Goals and Targeted Competencies, Core Learning Processes, and Key Instructional Design Characteristics

Domain Complexity →

Instructional Goal:[1]	Declarative Knowledge	Procedural Knowledge & Skill	Strategic Knowledge & Skill	Adaptive Knowledge & Skill
Knowledge & Skill Competencey:	Facts, concepts, rules; Definition, meaning	Task principles; Rule application	Task contingencies; Prioritization, selective rule application	Generalization of task rules, principles, & contingencies to new situations
Learning Processes or Mechanisms:	Exposure, encoding, recall & retention	Cue-response chains; Production compilation	Perception; Interpretation; Mental models; Decision making; Goal-performance regulation	Meta-cognitive monitoring; Situation awareness; Dynamic re-planning; Problem solving; Innovation; Invention
Emphasis:	Primarily Cognitive	Primarily Cognitive, Some Behavior	Cognitive/Behavioral	Cognitive/Behavioral Integration
Instructional Design Characteristics:	Proceduralized Strategies ←→ Active Learning Strategies Memorization — Experimentation Static Practice — Dynamic Practice Consistent Mapping — Variable Mapping Automaticity — Controlled Processing Outcome Feedback — Process Feedback Descriptive Information — Interpretive Information			

[1]Instructional Goals possess Guttman-scale properties such that more complex domain knowledge and skills subsume preceding, less complex levels.

Finally, the most advanced instructional goal is the development of adaptive knowledge and skills, which are predicated on strategic competency. Adaptability involves generalizing knowledge to novel situations and tasks, and this means understanding the situation as it evolves and extrapolating one's knowledge and skill to resolve unexpected shifts and novel challenges (Kozlowski, Toney et al., 2001; Smith, Ford, & Kozlowski, 1997).

As with more traditional training, we see task analysis as a critical prerequisite for designing distributed learning systems. One limitation, however, associated with conventional task analysis is that it focuses only on observable behaviors. Technology is increasingly being used to train individuals on cognitively loaded jobs that are complex, technical, and dynamic, and these jobs involve considerable judgment, knowledge, and experience. As a result, in DLS design it may be important to supplement conventional task analysis with a cognitive task analysis, which uncovers the mental aspects of job performance (DuBois, 2002; DuBois, Shalin, Levi, & Borman, 1997/1998). Cognitive task analysis focuses on the details of how a job gets done (e.g., decisions, strategies) and identifies the cognitive knowledge that assists in decision making, problem solving, pattern recognition, and situation assessment. This information can then be incorporated into instructional objectives to help ensure DLS focus on developing the cognitive knowledge that underlies strategic and adaptive expertise.

Finally, the DLS design process should include a person analysis, which evaluates the knowledge, skills, and abilities of trainees and considers the fit between the training and the trainees. This is particularly important in distributed learning environments given that DLS have the capability to create training programs that adapt in real time to individual differences in learners (Hawkridge, 2000). In other words, DLS have the potential to be configured to the characteristics of learners to support their strong features and mitigate their weak ones. Currently, however, the ability to design adaptive DLS is limited because relatively little is known about the effects of learner characteristics in such environments. A number of researchers have suggested that distributed training is best suited for individuals who possess certain attributes, such as moderate or high levels of cognitive ability, well-developed metacognitive skills, and sufficient prior knowledge (Brown, 2001; Schmidt & Ford, 2003). DLS typically provide learners with significant control over their instruction, and these attributes enable individuals to make better use of this control (DeRouin et al., 2004). When individuals lack these attributes, it is important to incorporate instructional supports tailored to individual progress that help guide learner choices and prevent premature termination (Bell & Kozlowski, 2002a). Research also suggests that a learning orientation, as compared to a performance orientation, can prompt an active approach to learning, characterized by higher levels of intrinsic motivation, enhanced metacognition, and better emotion control (Bell & Kozlowski, 2002b; Ford, Smith, Weissbein, Gullly, & Salas, 1998). Since active learning has been identified as critical in computer-based learning environments (Brown & Ford, 2002), it may be beneficial to design DLS capable of inducing a learning orientation among individuals who are naturally more performance oriented. Thus, although we are beginning to see systematic research on aptitude-treatment interactions in learning, until there is a firmer understanding of how various learner characteristics impact important learning processes and outcomes in distributed learning environments, it will be difficult to design DLS to take into consideration the information gathered through a person analysis.

In summary, a comprehensive needs assessment is essential to an instructionally sound approach to DLS design. Research on training needs assessment has historically been very limited (Salas & Cannon-Bowers, 2001), and the same is true for research on needs assessment within the DLS context. However, the issue goes beyond simply knowing what information to collect, but also understanding how to leverage the information to improve training design. Thus, in the next section we begin to examine how to the information collected during needs assessment can be used to drive DLS design.

Stage 2: Identification of Critical Learning Processes and Instructional Design Characteristics

The next stage of the heuristic shown in Figure 2 involves identifying the cognitive mechanisms and learning processes necessary to achieve the targeted instructional outcomes, and designing instruction so as to support these processes. For instructional strategies to be optimally effective, trainers and instructional designers must integrate learning models with instructional design practices (Salas et al., 2002). Contemporary theories of skill acquisition provide considerable insight into the cognitive-behavioral mechanisms that underlie the development of different knowledge and skill competencies (Anderson, 1982; Ford & Kraiger, 1995). For example, the acquisition of declarative knowledge necessitates repeated exposure to material and effortful encoding, whereas more advanced knowledge and skill acquisition requires a greater degree of self-regulation and knowledge integration. Ultimately, the purpose of instruction is to support these critical learning processes (Gagné, Briggs, & Wager, 1992). Thus, DLS will only be effective when they incorporate the instructional design characteristics necessary to stimulate and support the learning processes that promote targeted knowledge and skill acquisition.

Figure 3 highlights the linkages between different instructional goals, learning processes, and instructional design characteristics. Task analysis allows one to identify the instructional objectives and desired knowledge and skill competencies, which implicate different learning mechanisms. Once the emphasis of the training has been clearly established, it is possible to begin focusing on how to best support learning through the design of the instruction. For example, declarative knowledge is acquired through repeated exposure to material and the encoding of the material into memory (Anderson, 1982). As shown in Figure 3, this acquisition processes can be made more efficient by breaking down knowledge into its subcomponents, presenting easier material first, prompting continuous, static practice, and providing descriptive feedback that relates to the trainee what they did or did not learn (Ford & Kraiger, 1995; Kozlowski, Toney et al., 2001). Through repeated practice, declarative knowledge is compiled into procedural rules, which allow for faster, less error-prone performance (Anderson, 1982; Ohlsson, 1987).

As noted previously, strategic and adaptive expertise are based on the foundation provided by more basic knowledge and skills. For instance, it is not until knowledge and skills are internalized that individuals have the cognitive resources available to devote to strategy development (Kanfer & Ackerman, 1989). However, as highlighted in Figure 3, the development of more advanced competencies also requires a different set of learning processes and instructional design considerations. In particular, the development of more advanced competencies requires individuals to devote their cognitive resources to metacognitive activities, including planning, monitoring, and revising goal appropriate behaviors (Schmidt & Ford, 2003). In addition, attention must be focused on understanding the relationship between task demands and one's capabilities. These activities help trainees to comprehend the consequences of their actions, identify meaningful patterns in the transfer environment, and generate strategies for further knowledge acquisition and application (Ford & Kraiger, 1995; Glaser, 1994). As learners compile the consequences of actions, they are able to develop a knowledge structure or mental model that captures key task relations (Glaser, 1989) and enables adaptability (Kozlowski, Gully, Brown, Salas, Smith, & Nason, 2001).

In order to support these metacognitive activities, instruction should provide process feedback, which concerns how a trainee is using information or how behaviors are performed (Earley, Northcraft, Lee, & Lituchy, 1990). In addition, this feedback should be supplemented with interpretative information, which helps trainees extract meaning from the feedback. This information can be normative, providing trainees with a point of reference with which to compare the feedback information, as well as prescriptive, guiding trainees on what they should be doing or thinking next (Bell & Kozlowski, 2002a; Kozlowski, Toney et al., 2001). Experimentation and exploration can also be used to engage individuals' metacognitive processes. As individuals explore the consequences of their actions in a variety of contexts, they are able to induce the principles and strategies necessary for adapting their knowledge and skills to novel situations and problems (Hatano & Inagaki, 1986; Holyoak, 1991; Smith et al., 1997).

It is important to recognize that there exist cases in which instructional design characteristics at one end of the continuum can impede the development of knowledge and skills at the other end of the continuum. For example, constant, static practice is more efficient and effective than variable practice for developing declarative knowledge. However, when used during initial skill acquisition, constant practice can inhibit skill development and adaptability (Schmidt & Bjork, 1992). Thus, if the ultimate goal of training is strategic or adaptive skills, then variable practice will serve as a less efficient but more effective training design strategy. The potential for such conflicts underscores the importance of clearly establishing the goals of the instructional experience at the outset of the DLS design process.

In summary, the conceptual framework presented in Figure 3 provides the theoretical core of our approach to DLS design. Many of the highlighted linkages have been generated through research on learning in more traditional settings, yet this alignment also serves as the basic logic to guide DLS design. The next step is to extend this model into distributed learning contexts by considering how the instructional design characteristics can be delivered through technology. This is the issue we turn to next.

Stage 3: Identification of Necessary Instructional Features

As discussed earlier, considerable effort has been devoted to developing frameworks that distinguish DLS technologies on one or more dimensions. These frameworks have sometimes been used to argue for the superiority of one type of technology over another. Often overlooked in comparisons of different technologies, however, is the fact that the utility of a particular technology depends on the instructional goals and learning processes targeted by the training. Numerous researchers have argued that technological decisions should be based on the instructional goals of the training program. Noe (1999), for example, suggests that virtual reality and intelligent tutors should be used to learn complex processes related to operating machinery, tools and equipment, whereas CD-ROMs, internet, and intranet are best for learning facts, figures, cognitive strategies, and interpersonal skills. Although prior research suggests that technological decisions should be based on instructional goals and objectives, currently no integrative theoretical framework exists to guide such decisions. Most recommendations are based on anecdotal evidence or trial-and-error empirical research, and are narrowly focused on specific technologies or tasks. Thus, there is a need to map existing distributed training technologies and their associated capabilities onto different instructional goals and their associated learning processes, with the result being a theoretical framework that can be used to guide the technology selection process.

One necessary step in creating this framework is to determine the instructional potential of different distributed learning system features. The goal is to look beyond the technologies per se, and to focus instead on the kinds of instructional features – embedded in the technologies – that can be used to shape the learning process. Table 2 presents a basic typology of distributed learning features, classified into four primary categories that index the richness of the domain content/information, immersion, interactivity, and communication that can be delivered by distributed learning systems. Within categories, features are organized from low to high with respect to the richness of the information or experience they can create for trainees. The first category, *content*, concerns the richness with which information is delivered via the system to trainees. The second category focuses on features that influence *immersion* or sense of realism. This category concerns the extent to which the training captures the key psychological and contextual characteristics relevant to the performance domain. The third category, *interactivity* or collaboration potential, considers characteristics that can influence the potential degree and type of interaction between users of the system or between trainers and trainees. Finally, we consider features that influence *communication* richness or bandwidth, which determines the extent to which users can communicate via verbal and non-verbal means.

Table 2
A Typology of Distributed Learning System Features

Features that convey domain content and information:

- text
- still images/graphics
- images in motion (e.g., live broadcast, streaming video, recorded video, film, DVD)
- sound: voice, music, special effects (e.g., psycho-acoustically accurate 3D sound)

Features that influence immersion or sense of realism:

- pre-recorded experience
- psychological fidelity of constructs, processes, and performance skills
- constructive forces (computer generated participants) to simulate additional players
- stimulus space or scope (PC vs. 360 degree immersion vs. virtual reality)
- physical fidelity of situational context and operational features
- motion and action
- real-time experience
- adaptive to trainee inputs

Features that influence interactivity and collaboration potential:

- single participant at each site
- individual oriented learning
- multiple participants at each site
- team oriented learning

Features that influence communication richness:

- 1-way communication link
- 2-way communication link
- asynchronous communication
- synchronous communication
- audio only
- audio & video

Features are arranged from low to high information / experience richness.

By indexing these features according to their capability to create differing levels of information richness, it is possible to link them to the types of instructional experiences they can be used to support. Figure 4 represents an effort to map these linkages. In this figure, the design features outlined in Table 2 are aligned with the instructional objectives, competencies, and instructional design characteristics specified in Figure 3. One assumption that underlies this framework is that as the complexity of the knowledge and skills targeted in instruction increases, so too must the richness of the instructional experience. For example, when the goal is the development of basic declarative knowledge, experiential richness is less critical. The key to learning is repeated exposure to critical content, which can be done through one-way communication of text in a relatively isolated learning environment. In contrast, when the goal is the development of more advanced skills, a different set of instructional design characteristics becomes critical for learning including experimentation, variable practice, and rich feedback to stimulate and support metacognitive activity. Thus, at this end of the continuum, there is a greater focus on ensuring psychological and contextual fidelity, utilizing media and content to target multiple modalities, allowing trainees to interact with others in realistic situations, and facilitating real-time communication to support interaction and provide trainees with detailed and immediate feedback. If the targeted knowledge and skills involve working and coordinating with others, then it will be necessary to develop DLS that enable team members to work together (Ellis & Bell, in press; Marks, Zaccaro, & Mathieu, 2000). We now turn our attention to the final stage of the DLS design process, which involves selecting a delivery technology that can provide the necessary instructional features.

Figure 4
An Integrative Model Linking Instructional Goals, Competencies, Learning Processes, Instructional Design Characteristics, and Relevant DLS Design Features

Basic **Domain Complexity** *Advanced* →

Instructional Goals:	**Declarative Knowledge and Skill**	**Procedural Knowledge and Skill**	**Strategic Knowledge and Skill**	**Adaptive Knowledge and Skill**
Knowledge & Skill Competencies:	Facts, concepts, rules; Definition, meaning	Task principles; Rule application	Task contingencies; Selective application	Generalization of task rules, principles, & contingencies
Learning Processes or Mechanisms:	Exposure, encoding, recall & retention	Cue-response chains; Production compilation	Perception; Interpretation; Mental models; Decision making; Goal-performance regulation	Meta-cognitive monitoring; Situation awareness; Dynamic re-planning; Problem solving; Innovation; Invention
Instructional Design Characteristics:	Proceduralized Strategies ← Memorization Static Practice Consistent Mapping Automaticity Outcome Feedback Descriptive Information			→ Active Learning Strategies Experimentation Dynamic Practice Variable Mapping Controlled Processing Process Feedback Interpretive Information
	Richness of the Information, Interaction, and Instructional Experience →			
DLS Design Features: **Content:**	▪ text	▪ text ▪ still images/graphics	▪ text ▪ still images/graphics ▪ images in motion	▪ text ▪ still images/graphics ▪ images in motion ▪ sound: voice, music, special effects
Immersion:	▪ psychological fidelity	▪ psychological fidelity ▪ stimulus space or scope	▪ psychological fidelity ▪ stimulus space or scope ▪ fidelity of context/ops	▪ psychological fidelity ▪ stimulus space or scope ▪ fidelity of context/ops ▪ real-time ▪ motion and action ▪ adaptive to trainee
Interactivity:	▪ single participants	▪ single participants ▪ individual oriented	▪ single participants ▪ individual oriented or ▪ multiple participants	▪ single participants ▪ individual oriented or ▪ multiple participants ▪ team oriented
Communications:	▪ 1-way communication	▪ 1-way communication ▪ 2-way communication ▪ asynchronous	▪ 1-way communication ▪ 2-way communication ▪ asynchronous ▪ synchronous	▪ 1-way communication ▪ 2-way communication ▪ asynchronous ▪ synchronous audio & video

Stage 4: Technology Selection & Program Design.

The culmination of the theoretically driven DLS design process involves selecting a technology system or infrastructure that can deliver the level of information richness necessary to stimulate critical learning processes and develop targeted knowledge and skills. As noted previously, often technology selection serves as the onset of the DLS design process. This approach, however, ignores the fact that technology should be selected based on its capability to deliver the necessary instructional experience. Competent technology selection can only occur after one has specified the objectives of instruction and identified the level of information richness necessary on each of the DLS features to achieve those objectives. Thus, in our framework, technology selection concludes the design process so as ensure a calibrated DLS experience that will maximize both instructional effectiveness and practical efficiency.

Figure 5 illustrates how the DLS design features map onto specific technologies. The goal of the heuristic is not to present a comprehensive list of DLS technologies since technological combinations or variants create the potential for a vast number of DLS applications, making it difficult or impossible to catalogue every available technology. Rather, the heuristic includes a range of the prototypical and widely used DLS technologies to illustrate the level of information richness that may be achievable on each of the four critical instructional features using a particular type of technology. At the low-end of the continuum is printed material, which represents no-technology training. Because printed material is limited to text and images and is typically targeted at individuals, it is classified as delivering the lowest level of information richness. As one moves up the technology continuum, there is pre-recorded audio, video, and computer-based training. While such programs can deliver high levels of content richness and, when delivered through a computer, can enhance immersion, the level of interactivity and communication is low because these programs are typically individual-based and lack synchronous communication systems. Live video is next on the continuum and actually has two widely used forms. Satellite video is much like a video program, only live, because the use of one-way video and one-way audio limits communication and interaction. However, video conferencing programs are characterized by higher levels of information richness because there is two-way communication and interaction among students and between students and instructors.

Internet or intranet training is represented by three categories. Low-end web-based training simply involves the computerized delivery of text and is much like printed material except for the fact that some motion or animation may be integrated into the program. These page-turning HTML courses have been used widely due to the tendency to repurpose training manuals into web-based courses. Such programs do not take advantage of the opportunity to build in video and sound or create interactive content. As can be seen with the mid-range web-based training program, utilizing these features can increase content richness and the level of immersion. Finally, there are high-end web-based programs that not only utilize information rich content, but also incorporate support systems—such as chat, bulletin boards, or web cams—that increase the level of interactivity and communication.

Figure 5.
A Typology Linking Distributed Learning System Features to Specific Technologies

Technology	Prototypical Applications	Information/Experience Richness	
Traditional Text			
Printed Material	Training Manual	Content:	(Low: Text, Images)
		Immersion:	(Low: Minimal Psychological Fidelity)
		Interactivity:	(Low: Single Participant; Individual oriented)
		Communication	(Low: 1-way communication; asynchronous)
Pre-recorded Audio /Video/CBT			
Video & Audio Tapes	Training Video; Recorded Lecture	Content:	(Medium to High: Text, Images, Motion, Sound, Special Effects)
		Immersion:	(Low: Basic Psychological and physical fidelity)
		Interactivity:	(Low: Single participants)
		Communication:	(Low: 1-way; asynchronous)
Computer & Multimedia Software	CDROMs; Laserdisc; DVD; Computer-Based Training; Interactive Media	Content:	(High: Text, Images, Motion, Video, Sound, Special Effects)
		Immersion:	(Medium: Average Psychological and physical fidelity, Human-Computer Interaction)
		Interactivity:	(Low: Individual Oriented)
		Communication:	(Low: 1-way; asynchronous)
Live Video			
Satellite Communications (One-way video; one-way audio)	Remote Lecture	Content:	(Medium to High: Text, Images, Motion, Sound, Special Effects)
		Immersion:	(Low: Basic psychological and physical Fidelity)
		Interactivity:	(Low: Multiple participants but no trainer/trainee interaction)
		Communication:	(Low: 1-way communication; synchronous)
Video Conferencing (2-way video/audio)	Interactive, Live Instruction	Content:	(High: Text, Images, Motion, Video, Sound, Special Effects)
		Immersion:	(Medium: Average Psychological and physical Fidelity)
		Interactivity:	(High: Trainee-Trainee and Trainee-Trainer Interaction)
		Communication:	(High: 2-way, synchronous communication)

Figure 5 continued

Technology	Prototypical Applications	Information/Experience Richness
Internet/Intranet/Network		
Low-End Web-Based	Text Presentation (HTML page-turning program)	Content: (Low to Medium: Text, Images, Motion) Immersion: (Low: Basic Psychological Fidelity) Interactivity: (Low: Single participants) Communication: (Low: 1-way; asynchronous)
Mid-Range Web-Based	Web-based Interactive Media Program	Content: (High: Text, Images, Motion, Video, Sound, Special Effects) Immersion: (Medium: Psychological Fidelity, Potential for Human-Computer Interaction) Interactivity: (Low: Individual Oriented) Communication: (Low: 1-way; asynchronous)
High-End Web-Based	Web-Based Interactive Media Program with Group Support Systems (chat, bulletin board)	Content: (High: Text, Images, Motion, Video, Sound, Special Effects) Immersion: (Medium: Psychological Fidelity) Interactivity: (Medium to High: Trainee Interaction) Communication: (Medium to High: 2-way, synchronous communication)
Simulated Environments		
Individual Virtual Reality	Virtual Reality Program	Content: (High: Text, Images, Motion, Video, Sound, Special Effects) Immersion: (High: High Psychological Fidelity, Motion, Action; Adaptive) Interactivity: (Low: Individual Oriented) Communication: (Low to Medium: Potential for Human/Computer Communication)
Interactive Virtual Reality	Virtual Reality Program	Content: (High: Text, Images, Motion, Video, Sound, Special Effects) Immersion: (High: High Psychological Fidelity, Motion, Action; Adaptive) Interactivity: (Medium to High: Multiple participant/team oriented) Communication: (Medium to High: 2-way, synchronous communication)

At the highest end of the technology continuum are virtual reality programs. Virtual reality utilizes a three-dimensional representation of the environment to achieve high levels of content richness and immersion. Virtual reality programs can be either individual or interactive depending on whether a trainee is able to interact with others in the virtual environment. Even in individually oriented virtual reality programs, some degree of interactivity can be incorporated through scripted human-machine interactions. Overall, virtual reality has the potential to offer the highest level of immersion and interactivity.

Although the mapping is speculative at this point, our approach represents a significant improvement over previous attempts to link specific technologies to learning objectives that have been largely ad hoc and unsystematic. Figure 5 provides a starting point for research to empirically examine the ability of different technologies to offer specific levels of richness on the core DLS feature categories. As this typology is refined, it can guide the selection of core technologies, and variations would then need to be considered as a way to enhance the instructional potential of a particular technology.

Discussion

A Research Agenda for DLS Design

At the outset, we highlighted the tremendous benefits that DLS have to offer, not only in terms of cost savings and flexibility but also in their capability to offer innovative and powerful learning solutions; the potential for a revolution in training. Yet, the DLS literature is replete with examples of failed attempts to leverage distributed learning and the unbounded optimism associated with the early adoption of DLS systems has been tempered by these disappointments (Hamid, 2002; Taylor, 2002). To date, research and practice surrounding DLS has focused considerable attention on pragmatic concerns, but too little attention on critical instructional issues. We have outlined a theoretically-based approach to DLS design, which integrates learning models with DLS design practices. Given that this theoretical framework can guide decision-making at critical stages of the DLS design process, it has the potential to be a valuable tool for instructional designers and trainers. Research is needed to validate, evaluate, and refine it. In this final section, we propose a research agenda for DLS design, specifying key recommendations for future research and practice.

Recommendation #1: Needs assessment should serve as the foundation of the DLS design process. Given its critical role in DLS design, research is needed to build a systematic methodology for conducting needs assessment in distributed learning environments.

The first stage of our proposed DLS design process involves conducting a supplemented training needs assessment. This stage may be one of the most critical of the design process, because it is here that the goals of instruction are identified and important information regarding the environment and trainees is collected. This information serves as the foundation for decisions that are made downstream in the design process. Thus, unless the information gathered during the needs assessment stage is accurate and comprehensive, decisions made in subsequent stages of the design process will be compromised. Unfortunately, very little empirical research has been conducted in this area and, as Salas and Cannon-Bowers (2001, p. 477) note, training needs assessment "… remains largely an art rather than a science."

Research is needed to build a systematic methodology for conducting needs assessment in distributed learning environments. For example, traditional needs assessment practices may not consider a number of issues that are critical to the effectiveness of DLS, such as the adequacy of the technological infrastructure, the organizational climate for distributed learning, or person characteristics that influence one's ability to successfully engage in self-directed learning. We also noted earlier the potential value that cognitive task analysis may add to needs assessment in the DLS design process. Cognitive task analysis can help uncover the nature of expertise in complex and dynamic task environments, and this insight can prove vital for not only understanding the learning processes that DLS must stimulate and support but also for designing electronic tutoring and guidance systems (Salas & Klein, 2000; Zachary, Ryder, Hicinbothom, & Bracken, 1997). Yet, research is needed to develop a theoretically driven methodology that specifies the steps to take when conducting a cognitive task analysis, how to analyze the data, and how to link this information to essential learning mechanisms in the DLS design process (Salas & Cannon-Bowers, 2001). For example, Zachary, Ryder, and Hicinbothom (2000) describe an approach to cognitive task analysis in which individual performance in a real or simulated task environment is recorded and then the individual or a subject matter expert reviews the session and discusses the internal decision processes used to perform the task. Compared to more traditional thinking-aloud or retrospective approaches, this method is a less intrusive and more valid approach to eliciting information about the cognitive processes and knowledge elements that underlie performance. Finally, given the current rate of change in organizations, and the use of distributed learning to achieve just-in-time, adaptive learning solutions, it is necessary to supplement the DLS needs assessment with an analysis of future changes that may occur within the organization (e.g., technological changes) or on the job (Cascio, 1994; Schneider & Konz, 1989). This analysis will help extend the viability and relevancy of a particular DLS, but future research is needed to establish the best methods for collecting forward-looking information and using it strategically in the design of DLS.

Recommendation #2: Research is needed that maps the process pathways between instructional design characteristics, psychological processes, and targeted learning outcomes.

The second stage of the DLS design process involves linking targeted instructional outcomes to commensurate cognitive mechanisms and learning processes, and designing instruction to support these processes. In Figure 3, we used research and theory from a variety of disciplines, including cognitive psychology, education, and instructional design, to map these linkages. This integrative model serves as the theoretical core of our framework and provides a roadmap to guide the practical application of learning principles to the DLS design process. However, the linkages between the learning processes and instructional design characteristics need to be specified more precisely, which necessitates research that comprehensively maps the process pathways between instructional design characteristics, psychological processes, and targeted learning outcomes.

Brown and Ford (2002), for example, provide a theoretical model that suggests that computer-based training influences learning outcomes by affecting several key psychological processes, including mindfulness and training motivation. Mayer (2001) uses a cognitive theory of learning to discuss how the design of multimedia learning influences critical learning mechanisms and, ultimately, knowledge and skill acquisition. Other work in this area has developed a theory of design for technology-based training (Kozlowski, Toney et al., 2001), driving research that has examined the effects of instructional design and supports on the focus and quality of self-regulation processes, learning, and adaptation (Bell & Kozlowski, 2002a, 2003; Kozlowski, Gully et al., 2001). For example, there is an emerging body of work on the impact of active learning strategies (e.g., error training, mastery training) on self-regulatory processes, learning, and adaptation in technology driven-learning environments (Debowski, Wood, & Bandura, 2001; Keith & Frese, in press; Kozlowski, Gully et al., 2001). Further, research in this area is beginning to disentangle the differential effects of distinct instructional elements that underlie these techniques (e.g., Bell & Kozlowski, 2003), and to examine post-training self-regulatory processes and their impacts on trainee adaptation in transfer (Chen, Thomas, & Wallace, in press). By more precisely delineating specific intervention elements, their process pathways during training, and effects on skill retention and adaptation, such work will contribute to a comprehensive mapping of the linkages between core instructional features, key psychological processes, and core competencies, which can be used to refine principles to guide DLS design.

Recommendation #3: Research is needed to better understand the role of individual differences in distributed learning to guide the design of learner-centered, adaptive DLS systems that fit instruction to individual capabilities.

A related issue that must be considered involves harnessing the power of DLS to create learning experiences that are tailored to individual trainees. Recent research has revealed that some individuals naturally possess the cognitive capacity and self-regulatory skills necessary to succeed in distributed learning environments (Brown, 2001; Ford et al., 1998). However, for those individuals that lack these attributes, technology can be used to stimulate and support critical learning processes (DeRouin et al., 2004). Currently, two issues inhibit organizations' willingness and ability to design adaptive DLS.

First, the design of adaptive instruction remains a time consuming and resource intensive endeavor. For example, some estimates suggest that it takes a team of instructional designers and computer programmers between 200 and 1000 hours to design 1 hour of adaptive instruction (Murray, 1999). Given these high costs, many organizations do not believe that adaptive instruction will yield a positive return on investment. Research is needed, therefore, that examines the utility of adaptive DLS and also explores strategies for streamlining the design of adaptive instruction. In this regard, work that extends the design logic employed by Bell & Kozlowski (2002a) in their development of *adaptive guidance* represents one promising direction for future research. Unlike most efforts at intelligent tutoring, the design premise for adaptive guidance does not require the intensive development of domain, expert, and student models. Rather, the approach is benchmarked against normative learning curves which are far easier to develop and deploy in an adaptive system.

Second, the ability to design adaptive DLS remains limited because research is just beginning to understand the effects of individual differences in distributed learning environments. We see this as a more pressing issue because without a firm understanding of the effects of individual characteristics in such settings the design of adaptive instruction is simply not possible. As noted earlier, recent research has identified cognitive ability, metacognitive skills, and prior knowledge as relevant to learning in DLS (Brown, 2001; Schmidt & Ford, 2003). Future research is needed to better understand the role of these factors, and this line of inquiry should also be extended to include other individual differences. Goal orientation, for example, has recently been shown to play a critical role in driving the active learning critical in technology-based learning environments (Bell & Kozlowski, 2002b; Brown & Ford, 2002; Heimbeck, Frese, Sonnentag, & Keith, 2003). Personality characteristics, such as openness to experience or conscientiousness, have been identified as important predictors of trainees' motivation in self-directed learning environments (Ford & Oswald, 2003). The potential to use DLS to create powerful, individualized learning solutions is substantial, but future research is needed before this potential can be fully realized.

Recommendation #4: Future research must refine and extend the framework linking DLS features to the types of instructional experiences they can be used to support.

As future research refines the theoretical linkages outlined in Figure 3 and provides a deeper understanding of the role of individual differences in DLS environments, this information can be used to help guide the selection of DLS technologies. The theoretical core of our framework provides a tool that can be used to ensure that technology selection is driven by targeted instructional outcomes and critical learning processes. In Figure 4, we have provided a conceptual framework linking four categories of DLS features to the types of instructional experiences they support. Although the model presented in Figure 4 needs validation and refinement, it provides practitioners with a valuable tool to guide DLS design decisions. For example, one contribution of this model is that it moves beyond existing typologies of different training technologies and instead focuses on the instructional features embedded in the technologies that can be used to shape the learning process. This shifts the focus of the design process from choosing specific technologies per se, to selecting the cluster of technologies that offer the instructional experience necessary to achieve desired instructional outcomes. As technology evolves and new capabilities are developed, continuing research will be needed to update and expand the links between targeted instructional characteristics and distributed learning features. Yet, in the short term, these features should be relatively stable, at least more so than the technological systems that have been the focus of previous typologies.

Recommendation #5: Technology selection should serve as the endpoint of the DLS design process. Research is needed to map the instructional capabilities of different technologies.

The final stage of our proposed DLS design process involves selecting a technology system to deliver the training. In our framework, technology selection extends naturally from an understanding of the objectives of instruction and the level of information richness necessary on different DLS features to achieve those objectives. Technology serves as the medium by which the DLS features are integrated and delivered to the trainee, and therefore technology selection should act as the culmination of the design process. Figure 5 provides a preliminary typology linking distributed learning system features to specific technologies. At this stage, the mapping is hypothetical; thus, systematic research is needed to better understand the ability of different technologies to offer specific levels of richness on various DLS features. Nonetheless, in the absence of more compelling models, it can serve as a basis for application guidance. It offers more specific guidance for targeting application-oriented research that will help identify appropriate technology clusters and combinations for delivering particular instructional experiences. As new technologies and combinations of technologies emerge as viable distributed learning tools, research will be needed to build these into the framework and to provide more precise mappings of their capabilities. The conceptual framework we have developed provides practitioners with a systematic methodology for choosing a technological platform that will offer a calibrated DLS experience and maximize both instructional effectiveness and practical efficiency.

Conclusion

Powerful forces are afoot that are pushing organizational training out of the classroom and into workplace technologies. Although this shift in training delivery offers many cost and practical benefits, it also offers the potential to revolutionize training effectiveness by making training better targeted, learner centered, and adaptive. We believe that the set of integrated conceptual frameworks comprising our approach to DLS design, and the research agenda they drive, provide a point of departure to help ensure that potential is realized.

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