

RUNNING HEAD: DISTRIBUTED LEARNING DESIGN

A Theory-Based Approach for
Designing Distributed Learning Systems

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There has been steady growth in the use of distance learning and distributed training over the last decade (Salas & Cannon-Bowers, 2001), with some estimates suggesting that nearly 80 percent of all companies use some form of distributed, computer-based training (Kiser, 2001). Although there are a variety of factors stimulating this rapid growth in the use of distance learning and distributed training, what we refer to collectively as distributed learning systems (DLS), two have been key. One factor has been the practical benefits – lower cost, rapid deployment, and flexibility – associated with training systems that transcend space and time and enable training anytime, and anywhere. Another factor has been the advances in technology and connectivity. The penetration of computer technology into all facets of the workplace, the substantial increases in computing power and speed, and the interactivity enabled by the explosive growth of the Internet have provided a ready infrastructure for delivering distributed training. Indeed, the literature on distance learning and distributed training, both popular and academic, has been dominated by discussions concerning technological innovations and cost savings (Bell & Kozlowski, 2004; Kozlowski & Bell, 2002).

As is often the case, the factors stimulating the attractiveness of DLS have a negative side effect. A consequence of the heavy emphasis on practical benefits and technology is that researchers and practitioners alike 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 to guide training design for distributed systems (Salas, Kosarzycki, Burke, Fiore, & Stone, 2002). However, for DLS to be optimally effective, trainers and instructional designers must integrate learning models with instructional design practices (Schreiber, 1998; Welsh, Wanberg, Brown, & Simmering, 2003). It is critical, therefore, to develop a theoretical framework that can be used to guide DLS design. In the absence of such a framework, 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 chapter is to present a theoretical framework to guide DLS design and enhance the effectiveness of distributed learning. The framework we develop provides theory-based principles for specifying DLS design for achieving specific instructional goals. In contrast to much of the extant literature in the areas of distributed training and distance learning, our theory views the identification of desired instructional goals and associated learning processes—not technology—as the point of departure in DLS design. We believe these goals and learning processes should drive DLS design because they elucidate the optimal instructional experience, clarify critical instructional features, and determine the technologies most appropriate for delivering the features.

Designing Distributed Learning Systems

Overview

Recent reviews of DLS research (Bell & Kozlowski, 2004; Welsh et al., 2003) and the DLS design process (Kozlowski & Bell, 2002), and the opening chapter of this book (Fiore & Salas, in press) highlight the need for a conceptual foundation that provides a solid empirical basis for the derivation of scientific principles to guide instructional design for DLS. To a substantial extent, progress in this area has been impeded by researchers’ preoccupation with an important pragmatic concern: the bandwidth-cost tradeoff problem. That is, much of the research is driven by an examination of the degree of bandwidth and interactivity required for distance learning or distributed training to approximate conventional instructor-led classroom training. Although we acknowledge that this is an important practical concern, its primary attention to cost and technology factors has misdirected attention away from the need for a conceptual foundation—one driven by learning processes and mechanisms, not technologies—to guide the design of distributed learning systems.

The dilemma is that elements of the technology infrastructure are already in place or anticipated (e.g., the penetration of computer technology, enhanced connectivity, intranet and Internet access), the economic logic to harness the technology for training is compelling (e.g.,

upwards of 80% of training costs go for indirect support rather than directly to training), and the push to practice is rapidly diffusing early efforts (e.g., there are many well publicized e-learning efforts and initiatives in industry, education, and government). Thus, the availability of flexible technology, compelling economic drivers, and benchmark practices of early adopters are shaping the emerging nature of distributed learning systems. As a consequence, distance learning and distributed training programs are often driven by technology in terms of availability and cost, rather than by instructional goals linked to desired cognitive and behavioral competencies.

Current distributed learning design. The availability of technology and cost factors drive the selection of delivery media. Instructional issues typically receive little or no attention in this selection process. In fact, Govindasamy (2002) notes that most learning technology vendors "...deliberately distance themselves from pedagogical issues" (p. 288). Existing instructional content (e.g., manuals, lecture-based course materials), when available, is often then simply mapped onto the technology, a practice known as "repurposing." Because performance-relevant instructional goals are not the primary drivers of system design, attaining desired knowledge and skills as outcomes is more a matter of chance than intent. Moreover, there are two alternative outcomes that may be more likely. On the one hand, this technology-driven logic can yield training that is *inefficient* because it invests in more advanced technology than is necessary for delivering the desired skills. On the other hand, it can yield training that is *ineffective* because it fails to use technology with sufficient capability or bandwidth to deliver an instructional experience that develops desired knowledge and skill competencies (Govindasamy, 2002). This is, in essence, the core of the bandwidth-cost tradeoff. From our perspective, the current approach can only yield trial and error research and practice that attempts to map the boundaries of the tradeoff unsystematically. In the long run, it is likely to be a slow and costly approach.

A new approach. Our position is that the best way to begin to resolve this problem is to begin with a theoretical foundation that is driven by instructional goals and learning processes, not technologies. Training needs derived from the performance domain are used to identify desired instructional goals, which in turn implicate particular cognitive mechanisms and learning processes. Targeted cognitive mechanisms and learning processes next guide the identification of instructional features that specify the type of content that should be delivered, how much

immersion is desired, what degree of interactivity is necessary, and how much communication bandwidth is essential. Desired instructional features then guide the selection of appropriate technologies and the design of a theoretically grounded instructional experience. Technology selection is appropriately located at the end point of the design process—as a tool to ensure the delivery of an instructional experience that has been calibrated to fit training needs and instructional targets. The proposed approach can, in the near term, prescriptively suggest bandwidth targets that are likely to approximate the perimeter of the tradeoff and, in the long term, can better focus research in an effort to more precisely map the tradeoff curve. We believe that this approach will yield a more timely and cost effective research agenda to enhance the design of distributed learning systems.

Theoretical Foundation

We begin by developing a model that links instructional goals, desired knowledge and skill competencies, underlying learning processes and mechanisms, and necessary instructional design foci that deliver targeted skills. The model is designed to link the complexity of the instructional goal (basic to advanced knowledge and skills) to the types of instructional characteristics that would be necessary to stimulate underlying cognitive-behavioral mechanisms to achieve the targeted instructional outcomes. It is important to note that because instructional goals and associated knowledge and skill competencies are sequenced from basic to advanced, higher level competencies subsume more fundamental knowledge and associated learning mechanisms. This model and its conceptual linkages form the theoretical core of our approach.

In the second step we develop a typology that identifies categories of instructional features that contribute to different aspects of the design of an instructional experience. This approach is different than the more typical focus on technologies and the delivery features they possess (e.g., Noe, 1999). Our focus is not on technologies per se, although different technologies—singly or in combination—are implicated by these instructional features. Rather, the idea is to first focus on the key features that enable the design of an instructional experience. The selection of technologies becomes relevant later, when the DLS infrastructure is constructed. The central conceptual characteristic distinguishing instructional features within categories is the

information/experience richness of the instructional experience (low to high). As a general rule, greater information/experience richness necessitates wider bandwidth and greater cost.

Next, we integrate the theoretical core and the instructional feature typology. This integration provides a basis for prescriptive guidance to predict how information richness along particular instructional feature dimensions is linked to accomplishing desired instructional outcomes at different levels of knowledge and skill complexity. Thus, this integrative typology links our theoretical core to desired instructional features, thereby providing a theoretical foundation for the DLS design.

Finally, we map instructional features to discrete technologies to guide the combination of a technology infrastructure that creates a DLS. Although there are many ways of delivering different instructional features, we highlight several examples of how specific technologies can be used to deliver instructional experiences of varying levels of information/experience richness. Our goal in this final section is not provide a complete mapping of features to all available DLS technologies, but rather to provide several illustrative examples of the capability of specific technologies to deliver a feature-rich instructional experience. This logic underlying this mapping process can be extended beyond our examples to ensure that the technology selection for the delivery of an instructional experience is a consequence of theory-driven instructional design. By calibrating DLS delivery technologies to fit instructional goals and learning requirements, we believe that our approach will deliver cost efficient yet effective training experiences. Moreover, by helping to identify those pragmatic concerns that are least likely to be in doubt and those areas that necessitate further research, we also believe that our approach will guide research toward the derivation and validation of principles for guiding the design of DLS. We now develop the rationale of this approach in more detail.

Instructional goals, competencies, learning processes, and instructional design foci. This model within the overall framework forms the theoretical core of our approach. As shown in the uppermost section of Figure 1 labeled (a) *Knowledge and Skill Competency*, its foundation is provided by *instructional goals* that are sequenced on the horizontal dimension from basic to advanced knowledge and skill complexity. This developmental sequence is in conformance with contemporary theories of skill acquisition that postulate the progressive development of

knowledge and skill competencies, from facts to principles to contingencies to generalization (Anderson, 1982; Kozlowski, Toney, Mullins, Weissbein, Brown, & Bell, 2001; Ford & Kraiger, 1995). Learning processes for acquiring this progression of competencies differ qualitatively such that the acquisition of basic knowledge necessitates encoding and is memory intensive, whereas advanced knowledge and skill acquisition requires higher-level self-regulatory and metacognitive processes with an emphasis on integrating cognitive and behavioral skill. As a result, the differing learning processes that underlie different instructional goals along the developmental continuum implicate different *instructional design foci*. For example, at the basic end of the continuum instructional design needs to stimulate rehearsal strategies and memorization under consistent practice conditions, whereas at the advanced end of the continuum instruction needs to stimulate exploration and experimentation, variability in instructional stimuli and responses, and active, controlled reflection during practice.

The most basic instructional goal in the sequence is the acquisition of declarative knowledge, which entails basic domain content. It focuses on knowledge of the definition and meaning of important domain facts, concepts, and rules (VanLehn, 1996). It represents basic domain content or knowledge of *what*. Learning this competency involves repeated exposure to the relevant content, effortful attempts to encode the material into memory, and evaluation of current competency via tests of recall and retention as learning indicators and aids.

Through practice and experience declarative knowledge begins to be proceduralized (Anderson, 1982; Ohlsson, 1987). Procedural knowledge represents understanding of *how*. This process occurs with continued practice (repetition) beyond initial successes at reproducing certain behaviors. In addition, knowledge about situations, responses, and outcomes is integrated into the knowledge to form context-specific rules for application (Ford & Kraiger, 1995; Glaser, 1994). Proceduralized knowledge, therefore, can be described as a set of conditional-action rules, such as ‘If Condition A, then Action B’ (Anderson, 1983). With experience, condition-action rules are compiled or chunked together. As a result, as knowledge is proceduralized and compiled, individuals are not only better able to determine when knowledge is applicable but also are able apply what they know more automatically and efficiently.

As knowledge and procedures continue to be compiled, more elegant task strategies emerge. Cognitive resources are freed by the internalization of behaviors and those resources can be devoted to strategy development and self-regulation of action initiation and performance. As individuals develop strategies and a better understanding of task situations, they integrate this knowledge into more complex mental models. The mental models of experts contain diagnostic clues for detecting meaningful patterns in the learning or transfer environment (Glaser, 1989; Kraiger, Salas, & Cannon-Bowers, 1995). These richly interconnected knowledge structures allow experts to determine *when, where, and why* their knowledge applies. That is, they understand the conditions, timing, and rationale that yields effective task performance. Development of strategic knowledge requires variable practice and experimentation so that individuals can develop a complex network of structural relationships among important task concepts in the domain (Bell & Kozlowski, 2002; Kozlowski, Toney et al., 2001).

Finally, the most advanced instructional goal is the development of adaptive knowledge and skills, which are closely tied to the development of strategic knowledge and skills. However, whereas strategies are used to react to changing circumstances in a particular task context, adaptability involves generalizing and extrapolating knowledge to novel situations or tasks (Hatano & Inagaki, 1986; Holyoak, 1991). It represents knowledge of *what is happening now* and *what I should change next* to resolve the new problem or situation. Adaptability requires metacognition, which involves processes such as analyzing the situation, monitoring and evaluating one's learning progress, and controlling how to allocate one's resources and the prioritization of activities (Flavell, 1979; Schmidt & Ford, 2003). Metacognition enables an individual to recognize when a situation has changed, as well as to recognize when to discontinue a problem-solving strategy that would ultimately prove unsuccessful (Larkin, 1983). Adaptability involves dynamic re-planning and the ability to pull together task relevant knowledge to create an innovative, creative, and effective task approach. The development of adaptive knowledge and skills typically occurs well into the knowledge and skill acquisition process (Kozlowski, Toney et al., 2001). Individuals must have relatively complete mental models of the knowledge domain and these mental models need to contain not only valid causal relationships, but also error information that is gathered from variable practice and

experimentation. Existing knowledge and behaviors must also be internalized, because the greater the internalization the more cognitive resources are available for executive (meta-cognitive) functions (Kanfer & Ackerman, 1989).

To summarize the theoretical core, different instructional goals involve qualitatively different learning processes and appropriate learning processes have to be stimulated by the DLS to accomplish the instructional goal. This provides the basic logic to guide DLS design. A fundamental aspect of the sequence of instructional goals is that *complex competencies build on the foundation of basic competencies*. From a training systems perspective, one key implication of this aspect of the model is that training for advanced instructional goals must assure that (a) trainees possess basic domain competencies, or (b) the provision has to be made to target more basic competencies in the sequence prior to targeting advanced ones. In other words, the logic of the typology can be used to target particular instructional goals anywhere along this developmental progression, or to target the full sequence.

Distributed learning system features. As we have noted, the literature on distance learning and distributed training has been dominated by a focus on technologies, with technologies then driving the form of distributed instruction. Figure 2 catalogues the broad range of technologies that have the potential to be used in distributed learning and describes typical applications and examples. Although this approach can provide useful interventions, instructional design is ad hoc and the technology is not tailored to deliver an instructional experience linked to a model of learning. The instructional foci derived from the model shown in Figure 2 have the potential to be delivered in a myriad of ways via different technologies or sets of technologies. Thus, the purpose here is to look past the technologies per se, and to focus instead on the kinds of instructional features—embedded in the technologies—that can be used to stimulate targeted instructional foci, thereby shaping the learning process.

Our typology of *(b) distributed learning system features* appears on the left-hand side of Figure 1. It classifies DLS features into four primary categories that index the richness of domain content, 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 basic information (declarative knowledge) is delivered via the system to trainees. In its most sparse form, information is conveyed as text. Text is quite flexible, and is a near universal capability in most distributed learning systems. Additional features, such as still images and graphics, images in motion, and sound, can be added to basic text to enrich the information stream. It is important to recognize that more information is not necessarily richer information. Multi-media only enhances learning when it helps the learner understand and make sense out of the material (e.g, Mayer & Anderson, 1992). The second category focuses on features that influence *immersion* or sense of realism. This category concerns the extent to which the training captures key psychological characteristics of the performance domain (i.e., psychological fidelity) and, beyond that, draws the trainee into the experience—that is, creates a micro or synthetic world that captures their attention and subjects them to important contextual characteristics relevant to the performance domain (i.e., gradations of the physical fidelity of the experience) (Schiflett, Elliott, Salas, & Covert, 2004). This category is particularly important with respect to simulation design (e.g., distributed interactive simulation, DIS; distributed mission training, DMT), as it provides a basis to identify features that help to scale the immersion potential of lower to higher fidelity synthetic task environments (STEs) and task scenarios. The presumption is that psychological fidelity in terms of central constructs, processes, and performance measures provides an essential basic foundation for learning, and that gradations of physical fidelity add contextual realism that further grounds the instructional experience to important cues and contingencies present in the performance domain (Kozlowski & DeShon, 2004).

Up to this point, the two categories of features that have been discussed are common to all instructional systems, and represent important instructional design choices that shape the instructional experience. The next two categories, however, are unique to distributed learning systems in that they enable distribution of instruction via communication media and they shape the nature of the distributed instructional environment by determining the type of interaction that can ensue. They are the features that make the learning experience “distributed.” The category labeled *interactivity*, considers characteristics that can influence the potential degree and type of interaction between remote instructors and students, among distributed student peers, and,

potentially, among multiply distributed student teams or collaborative learning groups (e.g., Bouras, Philopoulos, & Tsiatsos, 2001; Collis & Smith, 1997). The potential range of interactivity is dependent on communication bandwidth, which is considered as a separate category. However, the interactivity category presents a set of design options in its own right. Given that instructors and students are distributed in space (and potentially in time), the issue here concerns the degree to which learning is centered around the individual learner in relative isolation, or whether learners are to be linked into clusters to enable teamwork or collaborative learning.

There is a growing theory and research literature that indicates training for teamwork skills—coordination, communication, and adaptability—necessitate training in a team context (Kozlowski, 1998; Kozlowski & Bell, 2003; Cannon-Bowers, Tannenbaum, Salas, & Volpe, 1995). Thus, instructional design for some applications of distributed learning—such as DMT and DIS involving teams and teams of teams—must incorporate considerations of team interaction as it relates to training desired performance competencies. In addition, there is also an emerging literature on collaborative learning that suggests appropriate instructional supports can help learners to teach each other, and that learners can learn more and better under collaborative learning conditions (e.g., O'Donnell, 1996; Rosenshine & Meister, 1995). Given the distance or potential absence of instructors, collaborative learning principles may have the potential to augment instruction and to supplement instructor guidance for distributed learning systems. How such principles could be applied would be constrained by whether students were independently distributed—necessitating remote collaboration—or whether they were distributed in cluster sites—allowing face to face collaborative learning.

The last category, features that influence *communication* richness, goes to the issue of communication bandwidth. Conventional face-to-face instruction places experienced instructors and students in spatial and temporal proximity. This enables the expert instructor to evaluate student learning in real time by monitoring student reaction cues (e.g., nodding vs. puzzled face) and testing for comprehension (e.g., asking a probing question). It also allows students to share views, perspectives, and comprehension with each other. However, when students are distributed in space (and potentially in time), real time access and processing of such latent communication

cues are dependent on the bandwidth of the communication link (Guzley, Avanzino, & Bor, 2001). And, even at its highest bandwidth (e.g., synchronous, real-time, audio-video link), latent cues and strategies for managing instruction, conversation, and exchange are degraded: field of view is reduced, the ability to gesture is limited, facial expressions are eliminated or constrained, auditory cues are diminished, tools and artifacts are difficult to share, and shared information is delayed or decoupled from its context. Indeed, these concerns regarding communication richness have formed the primary focus of research evaluating the effectiveness of distance learning relative to conventional face-to-face classroom instruction (e.g., Faux & Black-Hughes, 2000; Huff, 2000; Meisel & Marx, 1999; Wisher & Curnow, 1999). The essential question is: How much communication bandwidth is necessary to approximate the same instructional quality across environments? On the other hand, other literatures concerned with remote collaboration or computer-mediated communication suggest some positive aspects of lower information richness (e.g., asynchronous, time-delayed, text only) that may enhance information exchange, at least for some individuals. For example, status differentials are reduced, responses can be more thoughtful, and introverted or culturally dissimilar individuals may be more likely to participate (see McGrath & Hollingshead, 1994; McKenna & Green, 2002). In addition, communication can entail more than person-to-person conversation and production-blocking can be eliminated. Distributed learning systems will often necessitate information and data exchange exclusive of conversation. Thus, any way one considers the issue, communication bandwidth is an important consideration in the design of distributed learning systems.

Integrating instructional objectives, competencies, and features. Implications for DLS design that are provided by the integration of these two conceptual models is shown in the core of Figure 1 and labeled (c) *Integration*. Each DLS feature category is associated with a rectangular area demarked into two zones that correspond to the applicability of the feature(s) on the vertical dimension of *information/experience* richness to the targeted *instructional goal, competency, and instructional design foci* along the horizontal dimension. The key conceptual contribution is the diagonal demarking the two zones that posits the applicability of the instructional features to targeted instructional goals. The diagonal signifies the hypothesized degree of information/experience richness (i.e., bandwidth tradeoff) required to achieve targeted

instructional objectives. The white zone corresponds to those features that are essential to meeting the desired instructional goal. The shaded zone corresponds to those features that are optional, at the cost of additional technology and bandwidth. Although additional features may augment the instructional experience, they may not be necessary and may yield cost inefficiencies.

For example, when the targeted instructional goal is declarative knowledge, the diagonal references text as the primary content, psychological fidelity as the key immersion feature, single participants as the interactivity target, and one-way communication as the enabling link. In other words, the leading edge of the diagonal maps the most parsimonious, instructionally effective, and cost efficient features that should drive the specification of delivery technologies for the targeted instructional objective. Additional features—at the cost of greater bandwidth and more advanced technological infrastructure—may augment the instructional experience, but the tradeoff of cost efficiency relative to any increment in instructional effectiveness is an open question. Moving away from the leading edge of the diagonal into the shaded area suggests the potential degree of inefficiency. In contrast, when the targeted instructional goal is adaptive knowledge and skill, the leading edge of the diagonal references the highest degree of information/experience richness (and the subsumed lower level features) to accomplish the objective. That is, failure to utilize sufficient information/experience richness will likely yield ineffectiveness relative to achieving the targeted instructional goal.

The purpose of this model is to specify how instructional goals can be used to guide the selection of essential instructional features needed to provide an instructional experience of sufficient richness to achieve targeted objectives. Once the necessary instructional features have been identified, the next step is to select a technology system or infrastructure that can deliver the desired level of information/experience richness. We discuss this final stage of the process in the next section. The diagonal in Figure 1 represents the hypothesized bandwidth tradeoff. It is likely that—rather than a linear diagonal—the boundary or leading edge defining the essential and optional features is a nonlinear curve. Precise specification of this curve will necessitate targeted research to test and map the boundary. However, in the interim, the model can serve as a prescriptive and predictive tool for specifying cost efficient and effective instructional features

and delivery technologies for achieving particular instructional goals. We now turn our attention to the process of selecting a delivery technology that can provide the necessary instructional features.

Linking instructional features to DLS technologies. The final stage of the DLS design process involves mapping the necessary instructional features against potential delivery technologies. All too often, the selection of DLS technologies has served as the first step in the design process. The theory-based approach we advocate, however, views technology selection as an activity that concludes the DLS design process. Technology simply serves as the medium by which to deliver the instructional experience necessary to stimulate critical learning processes and develop targeted knowledge and skills. Thus, competent technology selection can only occur when one has first specified the goals of instruction and identified the level of information richness necessary on each of the four features to achieve those goals. Figure 3 provides examples of specific technologies that can be used to achieve different levels of information/experience richness on the four distributed learning features.

This goal of the figure is not to present a comprehensive mapping of instructional features to DLS technologies since technological combinations or variants create the potential for a vast number of unique DLS applications that can have very different capabilities. Rather, the figure is designed to illustrate the level of information richness that can be achieved on each of the four critical instructional features using different types of technologies. We also highlight the specific technological features that implicate the ability of these systems to offer different levels of information richness.

Focusing on content, one sees that the lowest level of information richness is provided by printed material, which contains only text and images. As one moves up the information richness continuum, there is web-based text, which has the potential to include motion, and then at the highest levels there is interactive, live instruction, which combines text, images, motion, video, sound, and special effects. As the technology utilizes a multimedia format there is an opportunity to present information so that it targets multiple sensory modalities (e.g., visual, verbal; Clark & Mayer, 2002; Mayer, 2001). Presenting content through multiple sensory channels can enhance

learning, although it is important to avoid overload since learners have a limited cognitive capacity (Mayer, 2001; Paas, Renkl, & Sweller, 2003).

Video-based programs provide the lowest level of immersion, offering basic psychological and physical fidelity. Immersion is enhanced by programs such as web-based interactive media programs, which create interactive content, but there is a significant jump in the level of immersion that is offered by virtual reality programs. Virtual reality offers a three-dimensional representation of the environment and provides an opportunity for realistic human-human or human-machine interactions. The result is high levels of both psychological and physical fidelity. With respect to interactivity, at the high end of the continuum is distributed interactive simulation (DIS), which is a PC-based, networked simulation that allows individuals to participate in hands-on exercises with other participants or teams. The programs typically simulate real-world environments and allow real-time communications and interaction, although the level of immersion is typically low due to a two-dimensional representation of the environment (Schiflett et al., 2004). In web-based environments, moderate levels of interactivity can be achieved by incorporating group support systems—such as chat, bulletin boards, or web cams—that increase the level of interactivity over individually orientated programs, such as CD-ROM programs.

Many web-based programs utilize one-way, asynchronous communication because information is being provided to the learner but the learner does not have an opportunity to communicate with the instructional system or other learners. To provide an opportunity for social learning in web-based environments, one can utilize online learning communities which allow learners to communicate with one another through text-based messaging (Johnson & Huff, 2000). When social learning is critical for achieving desired instructional goals, as it often is in team-based learning environments, more information-rich communication technologies, such as video conferencing, can be used. Video conferencing offers an opportunity for learners to not only communicate verbally but also an opportunity to send visual signals, which may be important when visual cues are critical to learning or task performance.

Although the examples above consider the distributed learning features individually, it is important to recognize that these features combine to create an instructional experience and it is

likely that the level of information richness required on one feature is not entirely independent of that required on other features. For example, if a high level of immersion is necessary for learning then the content will likely need to be presented through multiple sensory modalities. Similarly, if a high level of interactivity is desired, then it is also likely that 2-way, synchronous communication systems will need to be employed. Thus, it is important to consider these interconnections and to utilize a technology that can deliver the level of information richness necessary in all categories. This may necessitate the blending of different technologies in order to gain access to necessary features.

Conclusion and Implications

The growing utilization of distributed, technology-based training systems by organizations is both exciting and potentially problematic. Recent advances in technology have facilitated the development of a host of new and innovative training tools, such as virtual reality and interactive media, and have allowed organizations to devise training programs that transcend boundaries of space and time. At the same time, however, both research and practice surrounding DLS have been driven largely by pragmatic concerns, such as the bandwidth-cost tradeoff, and many critical instructional issues surrounding DLS have received little or no attention. In effect, the availability of flexible technology, compelling economic drivers, and benchmark practices of early adopters have shaped the emerging nature of distributed learning systems. As a consequence, there currently exists the potential for organizations to develop DLS that are ineffective for developing employee knowledge and skills. At best, organizations are likely to underutilize the instructional capabilities of distributed learning and, therefore, greatly limit their potential return on investment.

We have addressed this problem in this chapter by developing a theoretical framework that can be used to guide the design of distributed learning systems. In contrast to most of the extant literature, the framework is driven by instructional goals and learning processes, not technologies. We argue that DLS design should begin with the identification of desired instructional goals in order to identify specific cognitive mechanisms and learning processes. Targeted cognitive mechanisms and learning processes then guide the identification of the instructional features and content necessary to stimulate knowledge and skill development.

Finally, desired instructional features guide the selection of appropriate technologies and the design of a theoretically grounded instructional experience. We believe this approach to DLS design will ensure the delivery of an instructional experience that has been calibrated to fit training needs and instructional targets, thereby producing a more effective and efficient distributed learning system.

Implications for Future Research and Practice

Research implications. Given the limitations associated with the logic that currently drives DLS design, we believe the theoretical framework described in this chapter provides instructional designers and trainers with a valuable prescriptive tool. The theoretical framework provides a conceptual foundation for principles that can provide guidance at critical stages of the DLS design process. Nevertheless, the framework is preliminary, and it is important to conduct research to validate, evaluate, and refine it. Empirical work is needed to validate the proposed linkages between instructional goals, instructional design foci, and technology features; to evaluate how the fit between these conceptual dimensions impacts DLS effectiveness; and to refine the framework and its underlying principles.

One potential area of research focus in this regard is the leading edge demarking the boundary between essential and optional instructional features given a particular instructional goal and associated learning processes illustrated in Figure 1. Although the conceptual mapping represents the boundary as a linear diagonal, differences in information richness across the DSL features are not likely to exhibit smooth linearity in practice. Rather, it is more likely that specific DLS features will vary in their incremental contribution to information richness; some will add much, whereas others may add relatively little at any particular point along the knowledge and skill complexity continuum. Thus, the leading edge is more likely to be represented by a curve, and one with discontinuities for particular DLS features.

In the absence of precise mapping data, we believe the linear assumption inherent in the model is reasonable. However, the leading edge represents the cost/bandwidth tradeoff and, to the extent one is interested in maximizing impact while minimizing cost, the boundary needs to be more precisely mapped for different DLS features. Inherent in this process is the need for research to provide a more precise evaluation and cataloguing of the instructional

information/experience richness of different technologies. Research is also needed to explore how information richness may interface with other characteristics that define the instructional experience. For example, some researchers have focused attention on issues such as cognitive load or information processing (Clark & Mayer, 2002; Mayer, 2001; Paas et al., 2003). It is likely that information richness has implications for information processing and the cognitive load of trainees in that greater information richness is likely to necessitate more information processing, placing a larger cognitive load on the trainee (Kalyuga, Chandler, & Sweller, 1999). Research should also examine how different strategies, such as segmenting (allowing time between segments of material) or synchronizing (present corresponding visual and verbal information simultaneously), can be used to reduce cognitive load in information rich learning environments (e.g., Kalyuga et al., 1999; Mayer & Moreno, 2003).

However, in the interim, we believe the model is a valuable prescriptive tool for specifying cost efficient and effective instructional features and delivery technologies for achieving particular instructional goals. The theoretical framework we have developed can, in the near term, help guide distributed learning practice and, in the long term, stimulate a focused research agenda that will produce empirically grounded scientific principles to guide DLS design and ensure DLS effectiveness and efficiency.

Research extensions. Beyond the focus of this model—integrating instructional goals, learning processes, and the design of DLS technologies—other theoretical issues are also relevant to enhancing DLS design and thus are deserving of further consideration. For example, one set of issues that are particularly relevant concerns the integration of instructional supports that can be embedded in DLS design to further enhance the instructional experience. Some of these instructional supports are likely to be similar to those used in traditional learning environments (e.g., feedback), but how these instructional supports are designed and implemented may be influenced by the unique characteristics of distributed learning environments. Hamid (2002), for example, notes that “In an e-learning situation, a student is prone to frustration because of the technical skills required, the isolation, and because an online class lacks the built-in conventions. User frustration can be minimized through embedding support and feedback features such as chat rooms, active links, and perhaps by providing a time

management system” (pp. 314-315). Parush, Hamm, and Shtub (2002) consider metacognitive issues in the context of distributed learning, suggesting that it is important to build in functions that can support or enhance meta-cognitive activities. They added a learning history function in their study that facilitated the ability of learners to review and evaluate past performance. The issue of metacognition in synthetic task environments is also highlighted by Fiore, Cuevas, Scielzo, & Salas (2002), who focus on the importance of metacognition for training individuals for distributed mission teams. As another example of an instructional support strategy, work by Paas (e.g., Paas & Van Merriënboer, 1994) considers the use of “worked examples” in computer-based training to reduce the level of cognitive load experienced by trainees.

Our own work in this area of providing instructional supports in technology-based training has focused on learning processes and how the focus and quality of self-regulation can be leveraged via instructional design and supports (Kozlowski, Toney et al., 2001) to prompt active learning (Smith, Ford, & Kozlowski, 1997). Some of the more effective active learning tools include the use of mastery oriented vs. performance oriented goals to prompt more effective learning and adaptation (Kozlowski, Gully, Brown, Salas, Smith, & Nason, 2001); prospective adaptive guidance that guides the learner to make appropriate choices about what to study and practice given current levels of learning (Bell & Kozlowski, 2002); and the synergistic combination of instructional, motivational, and emotional control elements that prompt more effective self-regulation and learning in the open, learner controlled environment that typifies technology-based and distributed training (Bell & Kozlowski, 2003). The point is, the area of instructional supports is wide open for theory development and research, and it is an important adjunct to the basic theoretical foundation we have developed in the chapter. The next step in our systematic research effort will be to integrate it with the framework presented in this chapter.

Implications for practice. Influencing the practice of DLS design is the target of our approach, with principles to guide practice falling directly from our theoretical framework. Thus, the basic application of the model begins with the specification of desired instructional goals, targeted knowledge and skill competencies, and associated learning processes which then indicate the types of instructional foci or experiences that will be needed to develop the targeted skills and the sets of technologies that can deliver a corresponding instructional experience.

Clearly, the application of this approach will necessitate a multidisciplinary effort. Organizations or training design firms will need to utilize the services of instructional designers, educational psychologists, cognitive psychologists, and other specialists expert in the *science of learning*, working in partnership with computer programmers, web designers, and other technology and media specialists expert in the *art of creating an experience*. There is a pressing need for more cross-disciplinary interaction – achieving a balance between these design foci is critical.

Finally, we believe that return-on-investment models will need to consider the effectiveness of distributed learning from an instructional standpoint. That is, to what extent does a distributed learning system deliver targeted knowledge and skill competencies? The dominant focus on operating costs has produced what appear to be large return-on-investment estimates but, if learning is not considered, it is difficult to determine whether the program is really having the desired effect. This evolution of program evaluation is necessary to further shift attention to instructional issues in this field.

Conclusion

This chapter developed a theoretical framework that can be used to guide future research and practice surrounding the development, design, and utilization of distributed learning systems. Given the lack of existing theory and inadequacies of current research, the framework provides a foundation for a research agenda that is focused on the development of an elaborated set of scientific principles to guide DLS design and to address important theoretical and pragmatic concerns. Although there is no question that distributed learning holds the potential to enhance training and organizational effectiveness, a theoretically grounded approach to DLS design is needed if this potential is to be realized. We hope that this chapter serves to stimulate efforts to elaborate our approach.

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Figure 1

A Model Linking Instructional Objectives, Trainee Competencies, and Instructional Features

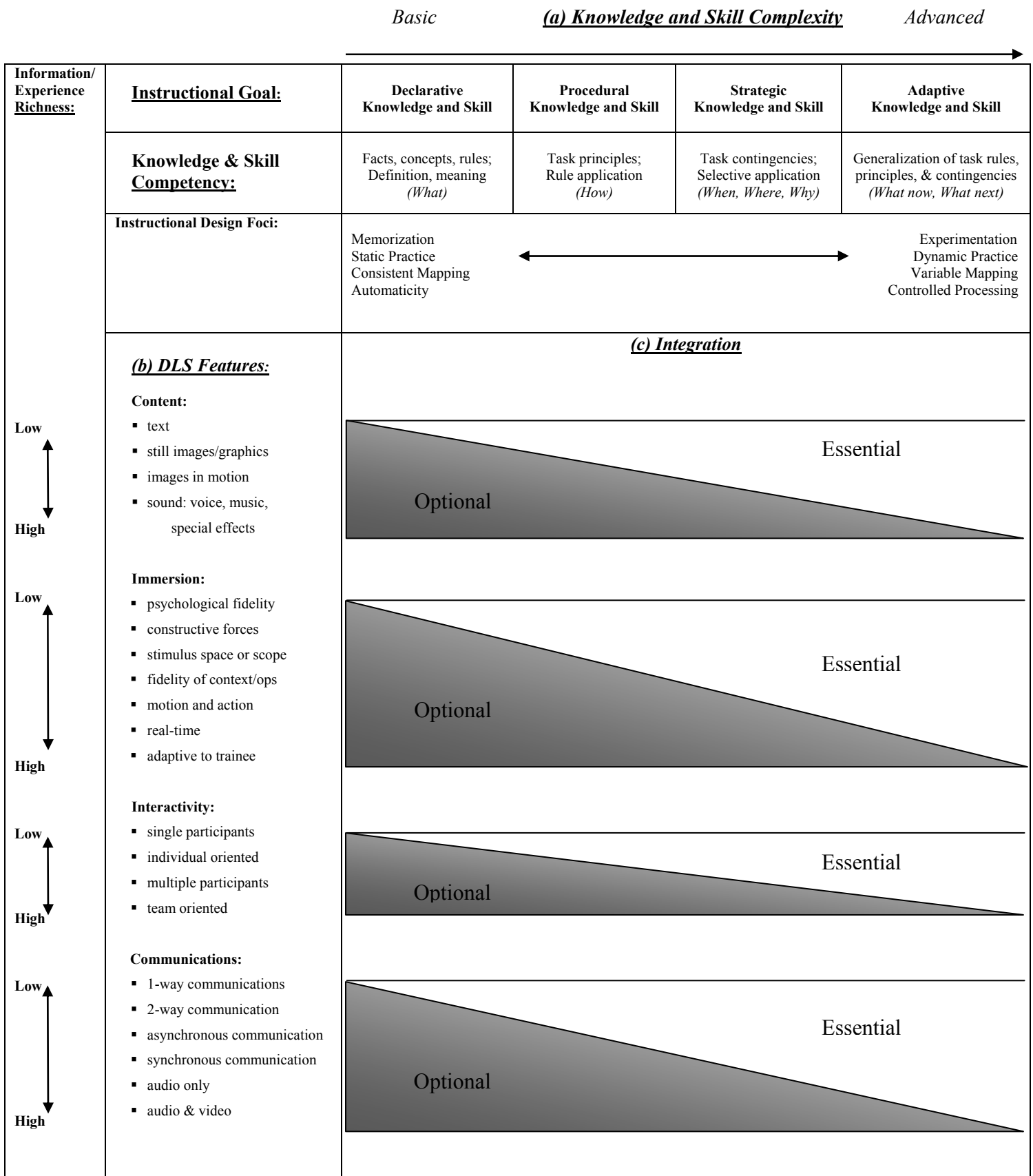


Figure 2

Distributed Learning System Technologies

<i>System</i>	<i>Primary Features</i>	<i>Examples</i>
CD-ROM DVD	<ul style="list-style-type: none"> Integrates text, graphics, animation, audio, and video. Computer-based delivery allows trainees to interact with content by typing responses, using a joystick, or utilizing a touch-screen monitor. 	<ul style="list-style-type: none"> Colorado Springs Fire Department has created digital simulations of fires on DVDs. Depending on decisions that trainees make throughout the program the fire either gets better or worsens. Dow Chemical places many of its training programs on CD-ROM so that employees can participate in the training where and when they want.
Interactive Video	<ul style="list-style-type: none"> Instruction is provided one-on-one to trainees via a monitor connected to a keyboard. Trainees use the keyboard or touch the monitor to interact with the program. 	<ul style="list-style-type: none"> Federal Express has an interactive video curriculum that covers courses on customer etiquette, defensive driving, and delivery procedures. Employees control the content they view and where and when they participate in the training.
Web-based Training	<ul style="list-style-type: none"> Can allow communication between trainers and trainees and among trainees. On-line referencing. Testing assessment. Distribution of computer-based training. Delivery of multimedia. Trainees can use hyperlinks to interact with the program. 	<ul style="list-style-type: none"> CIGNA uses web-based training programs to deliver training to its nurse consultants distributed around the country, many of them in rural areas. General Electric has created web-based environmental, safety, and health training in 17 languages to ensure compliance among its operating locations distributed around the world.
Virtual Reality	<ul style="list-style-type: none"> 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. 	<ul style="list-style-type: none"> Ford Motor Company uses virtual reality simulations to train new employees in its Vulcan Forge unit. Employees are fitted with a head-mount display that allows them to view the virtual world and they handle tools that are the same size and weight as those that they will use on the job. The virtual environment allows employees to learn the potentially hazardous job in a safe environment.
Intelligent Tutoring Systems	<ul style="list-style-type: none"> Refers to instructional systems that utilize artificial intelligence to provide individualized instruction. Trainee performance is analyzed to provide feedback and coaching and also to generate future scenarios and instruction. 	<ul style="list-style-type: none"> The US Navy utilizes an intelligent tutoring system in its officer tactical training. The system utilizes simulation and provides an automated evaluation of each students' actions. The system has enabled the program to be offered as self-study and learners receive 10-times more hands-on experience than before.
Electronic Performance Support Systems	<ul style="list-style-type: none"> 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. 	<ul style="list-style-type: none"> American Express uses an EPSS system to train its customer service accounts staff. The system helps employees to deal with problems by structuring information, coaching them, prompting for required information, and serving as a reference for information on company products and policies.

Figure 2 continued.

<p>Distributed Interactive Simulations (DIS); Synthetic Task Environments (STE)</p>	<ul style="list-style-type: none"> • Low fidelity, PC-based simulations of real-world tasks. • Linked by a standard interactive protocol, dispersed simulations can be linked together to emulate teams and teams of teams performing in a real-time virtual environment or micro-world. 	<ul style="list-style-type: none"> • The US military uses a variety of DIS and STE platforms to model team performance and conduct research on team effectiveness research (DDD, TEAM/Sim, AEDGE). As the psychological fidelity of these simulations improve, DISs and STEs are increasingly being used as basic training tools for military team effectiveness.
<p>Distributed Mission Training (DMT)</p>	<ul style="list-style-type: none"> • High fidelity simulations of real-world tasks, replicating operational equipment, procedures, and task demands. • Both “real” and constructed or virtual entities create a complex and rich performance context. • Linked by a standard interactive protocol, simulations located world-wide can be linked together to emulate teams and teams of teams performing in a virtual task environment. 	<ul style="list-style-type: none"> • The US military has experimented with a variety of DMT systems to gain experience and lessons learned for the development of this training technology. Examples include ROADRUNNER '98, SIMNET, and JEX. By allowing trainees to participate in a common, but complex and diverse battlespace, DMT systems allow the honing of high level skills, safely, and at low cost.

Figure 3

Illustrative Examples Linking Distributed Learning System Features to Specific Technologies

Level of Information/Experience Richness	Distributed Learning Features			
	Content	Immersion	Interactivity	Communication
<i>Low</i>	Printed Material (Text, Images)	Video (Basic Psychological and Physical Fidelity)	CDROM (Individual Oriented)	Web-based Text Presentation (1-way, asynchronous communication)
<i>Medium</i>	Web-based Text Presentation (Text, Images, Motion)	Web-based Interactive Media Program (Psychological Fidelity, Potential for Human-Computer Interaction)	Web-based Program with Group Support Systems (Trainee Interaction)	Online Learning Communities (Text-based, 2-way, synchronous communication)
<i>High</i>	Interactive, Live Instruction (Text, Images, Motion, Video, Sound, Special Effects)	Virtual Reality (High Psychological Fidelity, Motion, Action, Adaptive)	Distributed Interactive Simulation (Multiple participant/Team Oriented)	Video Conferencing (Video-based, 2-way, synchronous communication)