The New ISD

Applying Cognitive Strategies to Instructional Design

by Ruth Colvin Clark

Some claim that instructional systems design (ISD) is irrelevant or passé (Gordon & Zemke, 2000; Zemke & Rossett, 2002). I disagree. In an age when the economy depends more on the brains than on the brawn of its workforce, and when training dissemination via the Internet is ubiquitous, training that optimizes organizational performance is more germane than ever. In a projection of a future that is already determined based on demographics, Peter Drucker predicts, "The productivity of knowledge and knowledge workers will not be the only competitive factor in the world economy. It is, however, likely to become the decisive factor, at least for most industries in the developed countries" (1997, p. 22).

So how is ISD related to production of knowledge workers? Merrill suggests that ISD is "essentially a series of empty boxes, and we need more content for those boxes if we are to deliver better training" (Zemke & Rossett, 2002, p. 30). Thanks to the recent advances in cognitive science, we have a number of new tools and methods to fill those boxes, especially for training designed for knowledge work. Instructional technology is a design science that must guide the professional production of instruction. This article recommends a move toward evidence-based practice. In other words, we need to allow research rather than fads and folk wisdom to serve as the infrastructure for the professional practice of training design and delivery.

ISD—A Design Science

ISD is modeled after similar systems methodologies used in all professions that are based on design sciences, professions such as engineering and information technology. A design science is a career field that creates products built to achieve a practical goal. These fields share the following characteristics:

- systematic process that involves stages of planning, development, and testing
- scientific and technical principles in the design of products
- products designed to be functional *and* appealing to users

Engineers design bridges that support specified weight and vehicle dimensions, sustain given weather elements, and incorporate aesthetic qualities. Good information technology specialists design software that achieves business goals; meets specified data handling, data storage, hardware, and security requirements; and incorporates interfaces that make them easy to learn and to use.

Suggesting that the ISD process is no longer relevant to 21st-century training is equivalent to suggesting that engineers forget about design drawings or that systems analysts forgo data flow and process diagrams. The information technology designer and the engineer are building products whose performance failures are highly salient. The collapsed bridge or the crashed software system are noticeable and costly failures. While instruction end-product failures may not be as visible, the undertrained or mistrained worker can have even more insidious effects than the failed bridge or crashed software. At best, workers lacking skills exert an eroding effect on organizational goals and productivity. At worst, they put themselves and those they serve at risk in jobs with high safety consequences. Given the annual U.S. investment in organizational training of $60 billion (Galvin, 2001), the use of a systematic instructional design process whose heuristics are based on evidence is essential.

Rather than dismiss the ISD process as obsolete, I propose that the ISD boxes are still relevant and can be profitably populated by new models and techniques drawn from cognitive theories of learning. This is the basis for the new ISD.

Drivers of the New ISD

There are three driving forces behind the new ISD. First, increasing economic dependence on knowledge work demands a training emphasis on the invisible skills behind thinking and problemsolving. Second, research over the past 20 years has given rise to a new cognitive learning theory that in turn gives us new tools and techniques to apply to the design of instruction. And third, the emergence of technology to tag, store, and distribute knowledge objects makes the access to training broader than previously possible. The fundamental ISD process including performance analysis, design, development, and evaluation has not changed. What's new is a number of tools and techniques to fill the ISD boxes and a delivery technology that can universally disseminate training to anyone with a computer and modem.

Knowledge Work and the New Economy

Knowledge workers, from nurses to programmers, work with their hands and their heads. Often the most critical aspects of their work are the invisible ones, the problem-solving and analytic skills that are the hallmark of knowledge work. Not only are these decision and analytic processes invisible, but the expert practitioner often cannot articulate them. This shift in valued work from visible to invisible, from easily articulated to tacit, requires a new ISD, an ISD that focuses on defining and teaching mental processes as much as overt job procedures.

Cognitive Methods of Instruction

At the same time that the nature of work has shifted, research in the psychological sciences has undergone a quiet revolution, moving from behavioral to cognitive models of learning. According to cognitive models, learning is an active process during which learners construct new knowledge by integrating data from the environment with existing knowledge in long-term memory. Instructional methods that support this process mediate learning, while methods that disrupt the process are barriers to learning. The research in instructional psychology over the past 20 years provides a good start to a scientific foundation for design of effective instruction (Mayer, 2001; Good & Levin, 2001; Hannafin, Hannafin, Land, & Oliver, 1997). These new instructional methods also require a new ISD, an ISD that incorporates an understanding of how the memory systems and cognitive processes work during learning. By understanding the principles behind instructional decisions, professional designers can make informed decisions about their learning environments in which they appreciate the tradeoffs that are inevitable in real-world training production.

Technology and Training

While various technologies to deliver training via computer have been actively used over the past 25 years, only recently has universal access to the Internet made the distribution of training ubiquitous and the quality of the courses salient. Therefore, the opportunity to deliver training of high and low quality is magnified greatly. We know from hundreds of research studies that it is the instructional methods, not the media, that determine learning effectiveness (Clark, 1994). Everyone has had effective and poor training, both in the classroom and on the computer. In e-learning however, unlike some classroom training, quality cannot be hidden, it's on the screens for all to see.

The use of the computer to manage training systems also provides the opportunity to tag and store learning objects that can be uniquely assembled based on diagnosis of individual learner knowledge gaps. But unless knowledge objects are linked to job analysis and developed in accordance with cognitive principles of learning, even the most sophisticated management system will not improve work performance. In sum, a potent driver of the new ISD is the combination of universally available instruction with salient indicators of quality with the ability of technology to repurpose learning.

Filling in the ISD Boxes

The Job and Task Analysis Box

In early implementations of ISD, job observations and interviews were used almost exclusively to document the

Interviewer:	Which body system would you start with?
Expert:	Neurology.
Interviewer:	Why?
Expert:	I want to see if the patient is conscious.
Interviewer:	What would you do first?
Expert:	I would use my flashlight to examine reaction of the pupils.
Interviewer:	The pupils both react equally to the light stimulus by contracting. What does this result imply or mean? How do you interpret this?
Expert:	There's no brain damage…..

Figure 1. Cognitive Job Analysis PARI Interview
(Source: LaJoie et al., 1998).

actions and knowledge of the proficient worker. The focus was on explicit activities. This works well for many procedural tasks, such as use of a software system, where the actions can be seen and users can explain the reasons for their actions. But the focus on knowledge work involving problemsolving and analysis requires a shift from explicit to implicit knowledge. From systems engineers to intensive care nurses, the proficient knowledge worker can rarely articulate the mental models that are the source of their expertise. They have so much tacit knowledge stored in long-term memory that it's just about impossible for them to explain it verbally. For example, detailed analysis estimated that chess masters have about 50,000 play patterns stored in their long-term memories, patterns routinely used as the basis for game strategies (Simon & Gilmartin, 1973). As a result of these large stores of tacit knowledge, interviews don't get the full story. And in many cases, observing knowledge workers yields little: The important work is going on inside their heads.

Cognitive task analysis techniques have recently evolved to capture the mental processes of the knowledge worker. They use a structured interview and analysis process in which experts are asked to solve authentic job problems and at the same time to verbalize their problemsolving thoughts (Jonassen, Tessmer, & Hannum, 1999). As an example, PARI is a specialized interview strategy in which expert practitioners are asked specific questions as they solve a real job problem with which they are unfamiliar. PARI stands for prerequisite, action, result, and interpretation and lends itself to definition of structured problemsolving tasks such as troubleshooting.

To implement PARI, the practitioner is given a case problem and a question such as, "What would you do first?" As the practitioner describes an action, the interviewer asks what it was in the problem situation that prompted that action. The answer is the basis for the prerequisite. In other words, certain features of the problem prompt the expert to take a specific action. Once the action is taken, the result is recorded. The PARI sequence ends by asking the expert how he or she interprets the response to the action.

Figure 1 is part of a PARI interview of expert nurses solving a patient case used as the basis for designing an automated training program for intensive care nurses (Lajoie, Azevedo, & Fleiszer, 1998). The goal of PARI is to define the intangible iterative problemsolving processes of experts in terms of elements of the problem that stimulate a particular action (P and A), the outcome of that action (R), and the expert's interpretation of that outcome (I), leading to the next action sequence.

The Design Box

During the design phase of the ISD process, a blueprint of the instructional product is developed. Clark (2000) has proposed four main design architectures: receptive, directive, guided discovery, and exploratory. Figure 2 summarizes their major features.

While many courses incorporate two or more of these architectures, one typically serves as the dominant design model. The receptive architecture, typified by the lecture approach, assumes that learning is about absorbing information and teaching is about dispensing it. It is the oldest of the architectures and is still a pervasive approach in the classroom and on the computer. The directive architecture, reflecting its behavioral roots, assumes that frequent responses to questions with appropriate feedback mediate learning. The role of the instruction is to break content into small pieces and sequence the pieces from simple to more complex. These content pieces are presented in short lessons that include frequent questions with feedback. Early programmed instruction and much contemporary training use this architecture.

Architecture	Features	Example	Purpose
Receptive	Instruction provides information; few opportunities for overt learner activity	Lectures Readings	Briefings versus skill building; training for advanced learners
Directive	Bottom-up organization of content; small step size; frequent questions with feedback	Programmed Instruction	For teaching novices procedural skills
Guided Discovery	Instruction provides problems to solve, opportunities to try a skill, reflect on results, revise and retry	Cognitive Apprenticeship	For teaching principle-based skills to journeymen
Exploratory	Instruction provides rich resource repository plus good navigational aids	Using the Intranet for learning	For learners with prior knowledge and good learning management skills

Figure 2. Four Design Architectures.

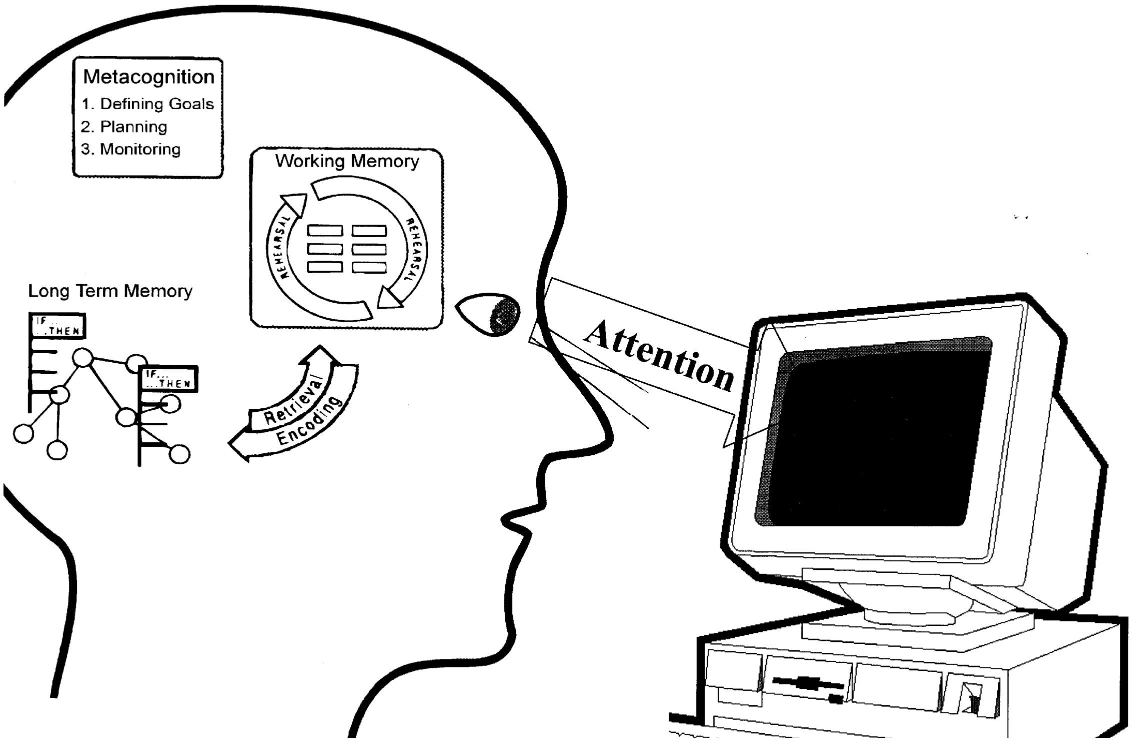

Figure 3. Cognitive Processes that Mediate Learning.

Guided discovery architectures assume learning to be an active constructive process mediated by problemsolving. The role of the instruction is to provide learners with authentic job problems to solve accompanied by relevant resources. The exploratory architecture is typical of many Internet learning environments that incorporate high levels of learner control. In the exploratory architectures, learning is about finding and processing relevant information while instruction is about developing a rich network of relevant resources along with easy navigation and search capabilities.

Each architecture has its appropriate place in instruction and is best applied depending on the goals of the training and the background knowledge and skills of the learners. During the design process, one of the architectures is used as a framework whereby the knowledge and skills defined during the job and task analysis are drafted into a blueprint for the training materials.

The Development Box

The development phase takes the design blueprint and turns it into an instructional product. It is at this stage that the architectures are populated with specific instructional methods. No matter whether the training is to be delivered on the Web or through a workbook and instructor in the classroom, the instructional methods dominate the quality of the result. And to be effective, instructional methods must support human cognitive processes.

Humans have two memory systems developers must consider when developing training: working memory and long-term memory. “Memory” is really a misnomer for working memory because it has very limited storage capacity. The common expression “seven plus or minus two” applies to working memory. Although its memory capacity is limited, it is in working memory that all active thinking and processing takes place. Research has revealed two separate storage areas in working memory – one to handle visual information and the other to handle phonetic or auditory information.

In contrast to working memory, permanent or long-term memory has a large capacity but no processing capability. As illustrated in Figure 3, new information must be processed or rehearsed in working memory in a way that it is integrated into existing knowledge structures in long-term memory. But it’s not enough to get information stored in long-term memory. After training is over and the learner returns to the work place, he or she must be able to retrieve the new skills into working memory. The challenge in instruction is to provide learning environments that manage the limited processing capability in working memory so that new information gets encoded into long-term memory in a way that it can be effectively retrieved or transferred later.

The sidebar on page 12 summarizes guidelines for best use of examples based on recent cognitive research.

Training Using the New ISD: An Example

In the section on cognitive task analysis, I illustrated a technique called PARI used to define the problemsolving mental processes of intensive care nurses. That job analysis was used as the basis for a guided discovery type of training

Design of Examples to Support Cognitive Processes

Examples are a well-known instructional method most training programs use. Research in the last 12 years, however, has provided a number of new guidelines regarding the optimal ways to select and place examples to maximize cognitive learning processes (Atkinson, Derry, Renkl, & Wortham, 2000). Four guidelines for best use of examples are:

1. Replace some problem exercises with worked examples to manage cognitive load.
2. Explain a visual example with audio rather than text when teaching in multimedia to manage cognitive load.
3. When teaching problemsolving or decisionmaking tasks, present several examples that look different on the surface but that illustrate the same guidelines to maximize transfer.
4. Train learners to self-explain examples to promote deep processing and maximum learning from examples.

Present Worked Examples

One challenge of instructional design is to preserve the fragile resources of working memory so they can be allocated to the processes needed for learning. A number of studies by Sweller, van Merrienboer, and Paas (1998) have shown that training time can be reduced and learning improved when worked examples are substituted for some practice problems. Thus in training requiring problemsolving, rather than showing one or two examples and then assigning ten practice exercises, it is better to show two worked examples, followed by a practice problem, and then two more worked examples, followed by another practice problem, and so forth. By using worked examples to build new mental models rather than spending working memory resources to solve problems, learning load is reduced and learning is made more efficient.

Use Audio

In multimedia learning, the modality principle prescribes that graphic examples are best explained by words presented in an auditory rather than a visual mode (Clark & Mayer, 2002; Mayer & Moreno, 1998). Applying the modality principle maximizes working memory resources by sending separate inputs to the visual and auditory centers in working memory rather than two inputs into the visual center, as would be the case with a graphic explained with text. By using the two storage areas in working memory, cognitive load is minimized.

Present Examples That Differ But Illustrate the Same Guidelines

The goal of instructional methods is to build mental models in long-term memory that will transfer effectively to working memory after training. Training can build specific mental models that apply only to limited situations or more flexible mental models that transfer to various situations. When training tasks that involve decisionmaking and problemsolving, such as selling or designing a new product, a more flexible mental model gives better performance mileage since it transfers to various diverse situations.

Build flexible mental models by using several examples that vary surface features but keep the illustrated principles consistent. For example, if you wanted to use best practice guidelines to sell a new product line, better transfer would result from showing several selling demonstrations (worked examples) that vary the client and the specific products than from showing one or two examples that used the same client and products.

Train to Self-Explain Examples

Research shows that training learners to self-explain examples consistently improves learning outcomes. (Atkinson et al., 2000). When faced with a worked example, learners can do one of several things. They may choose to ignore it. Or they may choose to process it at a surface level. But learning is maximized when learners actively study and encode the example. In this way the new mental models are actively constructed.

delivered by computer to accelerate the expertise of nurses entering an intensive care unit. As is typical of a guided-discovery environment, the learner is placed in a simulated problem environment and asked to take actions to resolve the problem. The interface is shown in Figure 4.

After reading the case background, the learner can take a number of actions to assess patient status, to formulate hypotheses about the causes of indicators, and to administer drugs. If the learner uses a tool or technique to assess patient status, the results are immediately reported by the system. At any point the learner can revisit his or her problemsolving steps and compare them to the steps an expert would take. Learning occurs as students take action, see the results, reflect on their approach, and retry when needed. This training is quite different from a more traditional directive approach which would present a series of short topical lessons about various patient assessment tools and techniques, interpretation of data, and potential responses to be made to various outcomes. Short-answer questions would follow each topic, with a case study at the end to provide an opportunity to integrate the lessons.

Which approach is better? Both have their place. The directive design is best applied to learning by novices. The short topics with frequent questions build a knowledge base from the ground up. However, the guided discovery approach works well, especially for problemsolving training for learners with some background in the domain. Van Merrienboer has proposed an instructional design model that integrates part-task procedural practice into whole-task problemsolving case exercises (van Merrienboer, 1997).

What's New About the New ISD?

In terms of the fundamental processes of performance assessment, job and task analysis, design, development, and evaluation, there is nothing new in the new ISD. What is new is adding the tools and techniques emerging from cognitive research. This research provides us with tools especially relevant for training of knowledge workers and for designing training for e-learning (Clark & Mayer, 2002). Specifically, techniques such as identifying tacit knowledge of knowledge workers, designing courses based on a guided discovery architecture, and using instructional methods to manage load in working memory or ensure transfer of new skills transform the old ISD into powerful processes to meet the performance requirements of the 21st-century organization.

Six Ways to Make ISD More Effective

Critics of ISD rightly point to the time needed to complete the process. To get the benefit of that time investment, ISD must be judiciously applied when and where it will pay off in improved job performance. Following are some guidelines:

- Be sure that training will improve performance. In many cases training is routinely provided without regard to causes of a problem. When other common performance drivers such as missing or inappropriate job goals, feedback, or incentives are the cause of a problem, training will not produce the desired results. Invest ISD time only in situations where a knowledge and skill gap will improve organizational outcomes.
- Concentrate training on critical skills. During the job analysis, identify factual or procedural information needed to perform tasks and package this information in a reference guide or support system. Invest ISD time in design of training only for those tasks that make substantial impact to critical job performance and that require demonstrations and practice to learn. For example, if developing training on a new software system, package procedural steps in reference or searchable help. Devote training to showing the capabilites of the software and to building confidence in using the software.
- Minimize receptive training. Instruction that relies primarily on lecture or reading fails to support active learning and is unlikely to promote learning except for advanced learners. Instead, consider your audience and the skills needed for job performance and use either directive, guided discovery or exploratory architectures, all of which provide frequent opportunities for practice.
- Repurpose training materials. Use technology to tag and store instructional objects so that training that results from an ISD process can be used for multiple purposes. In large organizations it is not uncommon for different divisions to create their training from scratch, including concepts and procedures common to many divisions. A corporate repository of instructional objects allows those divisions to build on materials prepared by others. Reusability also allows fast updates. A centralized repository of knowledge objects that can be updated and recycled will maximize the benefits of applying ISD processes to their creation.
- Develop job aids that support desired job performance and wrap the training around the job aid. Training must be integrated with the job. A well-designed job aid can serve as the bridge from the training class to the work environment. Smart job aids can embed performance support in the form of worked examples or wizards that allow learners to tailor training guidelines to their own work circumstances.
- Evaluate performance outcomes. Until we devote a more consistent and significant effort to evaluation, we are hard pressed to respond to those suggesting the death of ISD. To determine the payoff of ISD, the transfer of learning to the work environment must be assessed. This requires measurement of job performance indicators in addition to student reactions and skill tests that determine the practical impact of the ISD process.

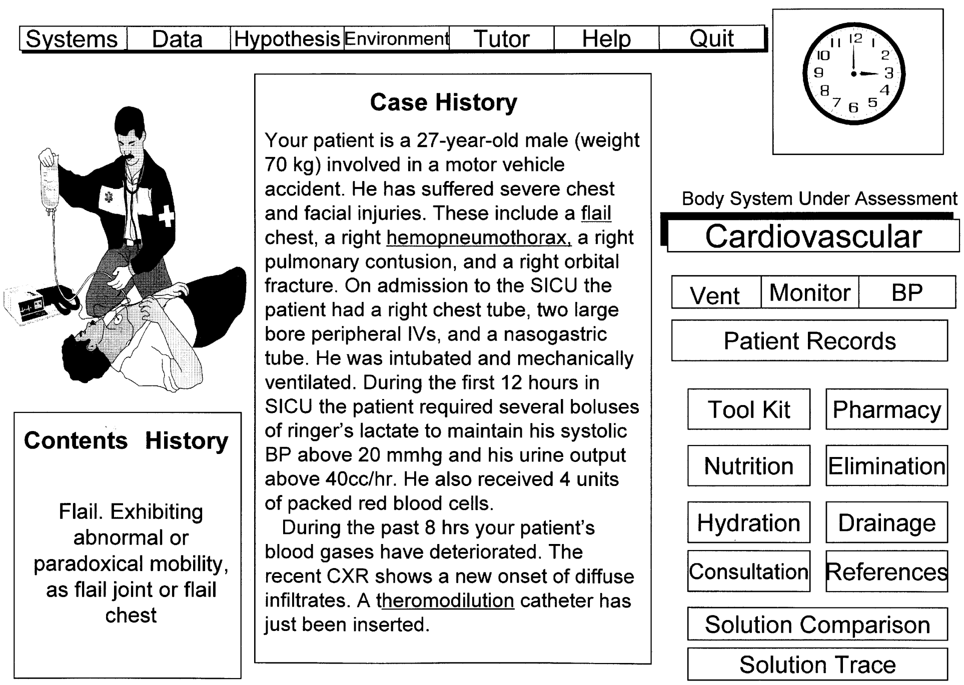

Figure 4. Multimedia Course for Intensive Care Nurses.

This article suggests that a new ISD that incorporates cognitive methods and research is needed to accelerate expertise in organizations. With technological capabilities to store knowledge products and to disseminate instruction broadly, effectively developed instruction that is based on an analysis of job performance linked to organizational goals is more critical than ever.

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