Four Architectures of Instruction

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Human expertise has become the infrastructure of the Information Age economy, and scarcity is already making the news. Reported in ***USA Today***, a study by the Information Technology Association of America predicts a growing shortage of information-technology workers this year with 850,000 jobs unfilled (April 10, 2000). In an economy based on expertise, training will continue to remain one of the critical elements of the HPT mix of interventions. Furthermore, the ubiquitous access to information and training now provided via the Internet demands effective instructional interventions to realize its potential. Unfortunately, the human information processing system cannot absorb information at the rate and complexity that technology can deliver it. Effective instruction in any delivery medium must accommodate the limited resources of working memory, the encoding and transfer of skills between working memory and long-term memory, and the metacognitive regulation of learning. In this article I will describe 4 instructional approaches which vary widely in their assumptions of learning and provide guidelines as to the use of each.

One Size Does Not Fit All

The behavioral instructional strategies that have provided the intellectual foundation of our Instructional Systems Design (ISD) approaches to learning make assumptions about learning processes that are applied to most individuals. That is, learning is assumed to be a similar process in all individuals and for all tasks, and thus many people feel a common instructional approach should suffice. The more recent cognitive and constructivist approaches to instruction emphasize differences in individual information processes that require unique training interventions. The cognitive-behavioral dichotomy itself promotes a limited perspective that there is one better approach to instruction. In fact, there are significant cognitive and motivational differences among individuals that point to different instructional strategies as a function of prior expertise, metacognitive skills, and motivational predispositions.

In addition to differences in human cognitive processes, different job outcomes will require diverse instructional approaches. It is convenient to distinguish between near or procedural skills and far or principle-based skills. Near transfer or procedural tasks such as accessing your e-mail are performed the same way each time. In contrast, far transfer or principle-based tasks such as closing a sale require the individual to make significant adaptations each time the task is performed. The instructional strategies to optimize success in performance of near and far transfer tasks are different.

Four Instructional Architectures

To characterize different instructional approaches that best fit different processing and task requirements, I have proposed four predominant strategies of instruction that I call Instructional Architectures (Clark, 1998). Although to depict all training as falling into one of four architectural types is an oversimplification, my goal is to provide a taxonomy that can be used to consider different strategic approaches for meeting varying human cognitive and performance task needs. Below I provide brief descriptions, examples, and prescriptive guidelines for each architecture: Receptive, Behavioral, Guided Discovery, and Exploratory.

Receptive Architecture

The most ancient and still highly prevalent training methodology today is a receptive style of instruction. Receptive instruction assumes that learners can absorb knowledge and skills when they are exposed to them such as when listening to a lecture, watching a video, or reading text. The most predominant feature is the lack of externally prompted interaction. A metaphor is the learner as a sponge and the instruction as a vessel of water to be absorbed. In general, receptive models of training are highly instructionally controlled in that the instructional source controls the content and sequence of information and in the case of classroom lecture or video, the rate of delivery as well. Receptive training varies a great deal in its use of specific instructional methods such as examples, analogies, visuals, and sequencing of information.

Cognitive Impact

Receptive architectures pose two main challenges to human cognitive processes: cognitive overload and long-term memory (LTM) encoding failures. In addition, receptive architectures require learners to have good self- regulatory mechanisms- known as metacognitive skills- to learn effectively from them.

***Cognitive overload*.** The limited capacity of human working memory has long been known and has recently given rise to a stream of research on instructional methods that manage load (Sweller, Van Merriernboer, & Paas, 1998). In general we know that the processing capacity of working memory is a function of prior experience. Thus, a more experienced participant in a given subject matter can handle greater imposed load. In receptive training that is instructionally controlled as to content, sequencing, and rate of delivery, overload can result; especially if other load-management strategies such as integrated audio and visual displays are not used. A classic example is the college lecture delivered rapidly without supplementary visual support that requires a novice learner to take full notes.

***LTM encoding failures*.** For learning to occur there must be a rehearsal of information that connects new knowledge in Working Memory (WM) to existing schemas in LTM. Such rehearsals are commonly promoted in instruction via practice exercises. Since receptive architectures are characterized by a lack of imposed interaction, it is up to the learner to take initiative to encode the new information. For a learner with some experience in the content and good self-managed learning skills, encoding may occur. However novice learners with poor metacognitive skills will be at risk in this architecture.

***Metacognitive skills*.** Metacognition refers to the ability to assess and manage internal learning processes. It is distinct from intelligence but correlates with success in many instructional environments. Receptive architectures will require good metacognitive skills on the part of learners since there is often little instructional support built into the training.

When to Use

I make a distinction between briefings or information delivery AND training which is designed to build skills. The receptive architecture, especially when supported with written materials, can provide a good source of information for briefing purposes. However for skill building it poses risks for novice learners, especially those without good learning management skills.

A recent research study entitled “A Time for Telling” describes interventions that can enhance learning from a lecture (Schwartz & Bransford, 1998). Different assignments in conjunction with a lecture on psychology concepts were compared. Learning was measured one week later using a test that required predictions based on new case scenarios (e.g. an application test). They found that asking learners to study and analyze contrasting cases that consisted of simplified experimental designs and data from classic psychology experiments followed by a lecture or textual reading resulted in better learning than just reading the cases and hearing a lecture, summarizing a relevant text and hearing a lecture, or analyzing cases twice with no lecture. The authors conclude “ teaching by telling can play a significant role in deepening students’ understanding if the students have had a chance to acquire appropriate prior knowledge. In these studies, contrasting cases provided students with the differentiated knowledge structure necessary to understand a subsequent explanation at a deep level.” (p. 504).

Another related study examines individual variables that predict successful learning in a receptive mode (Britton, Stimson, Stennett, & Gulgoz, 1998). Using a factor analytic approach, the research team finds four main factors that predict successful learning from reading text:

1. metacognitive ability to recognize learning deficiencies,
2. working memory capacity,
3. inferencing ability (e.g. the ability to extend and connect information in a reading beyond the context of the reading itself), and
4. prior knowledge in the specific subject domain of the reading.

The results support a process model indicating that first metacognitive skills are needed to detect that the learner does not understand the text. This detection results in mental activities based on inferencing and working memory capacity that stimulate the connection of ideas in the text to each other and to existing ideas in LTM which result in learning from the text. The authors suggest that these processes may be innate, may be learned fortuitously, or could be learned via instruction. Instructional strategies would need to focus on improvement of metacognitive ability, inference making ability, working memory ability, or domain knowledge; improvements in any one of these should result in improved learning even if other abilities are held constant.

Behavioral Architectures

In its infancy the International Society for Performance Improvement (ISPI) was called the National Society for Programmed Instruction (NSPI). The Society was born with an inheritance that promotes instruction of a behavioral nature. Based on a stimulus response model, behavioral instruction assumes that learning occurs by a gradual bottom up building and association of skills, which are strengthened by correct learner responses to carefully constructed and tested interactions. Thus the role of the learner is to respond correctly to frequent interactions embedded into the instruction. Behavioral architectures tend to emphasize:

1. bottom up hierarchies in which prerequisite knowledge and skills are sequenced before more complex knowledge and skills
2. chunking of instruction into relatively short lessons that build on each other
3. frequent interactions to build the skill hierarchies in the learner
4. effective feedback to provide knowledge of results and promote subsequent adjustments by the learner

Much early Computer Based Training (CBT) adopted this model, and it is widely prevalent in training programs today. Figure 1 illustrates a portion of a contemporary multimedia program designed by Learning Edge Corporation that uses a behavioral approach to teach a new telephone system to customer service representatives. After a demonstration lesson, the learner is guided step by step through the procedure. In the event of an incorrect response as illustrated in Figure 1, the learner is given a hint and asked to try again. After two incorrect responses, the program demonstrates the correct sequence of action. The main menu provides the learner with a series of lessons in which more basic skills are taught in early sequences followed by more complex skills as the program progresses.

Cognitive Impact

Behavioral architectures are especially effective at managing cognitive load and encouraging encoding into LTM by frequent interactions. In addition they supplant metacognitive skills by frequent use of advisory or diagnostic feedback and instructional control of content sequencing.

Cognitive load. By providing a disciplined bottom up sequence of small learning chunks accompanied by frequent interactions, behavioral architectures keep cognitive load relatively low. While this will be helpful for novice learners, individuals with more experience find the approach to be “overkill” and motivation and subsequent learning may be depressed.

Figure 1. A Behavioral multimedia lesson to teach use of a telephone system. Courtesy of Learning Edge®

LTM encoding failures. Assuming that the interactions placed in behavioral instructional programs are meaningful – not just rote repetition from memory – encoding of transferable skills into LTM is promoted. This will benefit learners who are novice to the domain and who lack the prerequisite knowledge necessary to generate effective interactions on their own.

Metacognitive Support. By providing chunking, bottom up sequences, and frequent interactions, metacognitive support is embedded into the instruction. Learners do not have to make many decisions as to the order of instruction or how they will encode new information. This will compensate for the lack of such skills in some learners. However, by constantly providing metacognitive regulation in the training, the learners will not get opportunities to build their own metacognitive skills. We will look to other architectures for methods that require learners to manage their own learning processes and thus build metacognitive skills.

When to Use

As a tried and true approach to instruction, behavioral architectures have proven successful for learners who are new to the domain being taught and who may lack good metacognitive skills. In addition, they have proven successful for the instruction of procedural skills where a bottom up, step by step approach practiced in a realistic job environment effectively supports learning of near-transfer skills. However for learners who are experienced in the domain of study and for learning of far-transfer skills, behavioral approaches may not be the most effective strategy to use.

Situated Guided Discovery Architectures

As summarized by Walberg & Haertel (1992), and Reynolds, Sinatra, & Jetton (1996), instructional theorists have increasingly turned toward cognitive and social models of learning for guidance in the last twenty years. From the work of a variety of social and cognitive psychologists have emerged learning theories that are more 'constructivist' in nature. Constructivists and social constructivists support the idea that learners working alone or in conjunction with others internally generate unique knowledge structures (Phillips, 1995). The role of the instruction is to provide resources and experiences that promote the internal construction of new knowledge and skills. Compared to the behavioral architectures, the guided discovery approaches emphasize the building of unique knowledge bases versus consistent acquisition of predetermined knowledge and skill hierarchies.

Business and industry has applied the guided discovery approach through case-based learning. Figure 2 illustrates a screen from a multimedia case-based training called " Fair Lending" designed for bank loan agents developed by InterWorks â for the Bank of America. A case presented by a loan applicant can be researched using an applicant interview, credit checks, bank reference, and policy procedure guides all accessed from the desktop environment. Unlike the "right or wrong" feedback characteristic of behavioral instructional programs (See Figure 1), feedback in guided discovery tends to be multisourced and naturalistic. For example, feedback in the Fair Lending program comes from the corporate lawyer who provides immediate commentary on illegal questions asked during the interview, your commissions earned displayed on your desktop calculator, your performance time demonstrated on your desktop clock, and a performance appraisal given by your manager at the end of the game.

Figure 2. Guided Discovery multimedia course for bank loan agents. Courtesy of InterWorks®

In contrast to behavioral instructional models, the organization of guided discovery architectures is more global than bottom up. Learning is situated in a realistic work problem. Learner control is much higher, allowing the participant to access a diverse array of resources and advice to solve the problem. Feedback is typically not of the right or wrong variety but attempts to model actual consequences of real-world activities. There is also a more pervasive emphasis on collaborative learning in small group settings. For specific guidelines on developing Guided Discovery architectures see Clark (1998) and Jonassen (1999).

Cognitive Impact

Guided Discovery architectures may challenge cognitive load and will demand good metacognitive skills by learners. Because they are case based, by design they should promote encoding into and transfer from LTM of job-relevant skills.

Cognitive load. By using a case-based approach, the more global nature of the instruction, combined with high levels of learner control, may overload working memory of domain novices. If the audience background is heterogeneous, opportunities to access a more behavioral instructional sequence should be integrated into the instruction. This will provide the more novice participants in the audience the greater structure inherent in the behavioral approach most appropriate to their cognitive requirements.

LTM encoding. Constructivist approaches are built on the assumption that learners must actively construct their new knowledge and skills. By design they provide environments which are heavily interactive and facilitate encoding. To the extent that cases are situated in real world environments, transfer of learning from Long Term Memory (LTM) back to working memory (WM) on the job should also be enhanced.

Metacognitive Support. Guided Discovery instruction requires learners to grow and use their metacognitive skills. The high levels of learner control and opportunities to access diverse resources and follow various paths to case solutions all demand metacognitive monitoring. Many guided discovery programs allow learners the opportunity to rework their solutions to make improvements a second or third time.

When to Use

Guided Discovery architectures are still relatively new, and their effectiveness has not always been fully evaluated. In a study on the effectiveness of a problem-solving case-based training program called Sherlock which uses multimedia simulation to teach troubleshooting of specific electronic equipment, 25 hours of instruction was found to result in the equivalent skills of a technician who had performed the job for four years (Lesgold, Eggan, Katz, and Rao, 1993). While this may seem magical, the cases provided in simulation form compress time by providing a diverse sequence of problems to solve in a brief time. In general for business and industry, these designs are ideally suited for more experienced learners and for more far transfer skills that involve problem solving.

One recent research study compared a strategy of discovery learning with providing worked examples (a more behavioral approach) in the learning of a database program (Tuovinen & Sweller, 1999). Both groups of learners received a classroom introduction to a database program, which included practice exercises to be performed on the computer. After an initial common lesson, subsequent lessons varied. The exploration group read a text on the lesson skill and was directed to “try out the functions in situations you create yourself using databases provided.” The worked-examples group was given a worked out example followed by a second example they were directed to complete. This pattern was used for 6 practice questions. Learning was assessed by a test with problems similar to the training (e.g. application test). Results indicated an interaction in which learners novice to databases did better with the worked examples approach while learners experienced with databases showed no significant differences with either condition. The authors conclude that worked examples helped manage cognitive load in inexperienced students but "if they have sufficient domain knowledge, the format of practice is irrelevant, and discovery or exploration practice is at least as good, or may even be better, than worked-examples practice" (p. 340). It should be noted that there are differences in discovery learning as implemented in this study and guided discovery, which imposes greater instructional structure. In addition, this study focused on a relatively near transfer skill, which would lend itself more appropriately to a behavioral approach.

In terms of design complexity, the guided discovery architecture of the type illustrated in Fair Lending will tend to be greater and often more costly – all things being equal – than either behavioral or receptive architectures. Will this significantly greater investment incurred in the design be offset by the acceleration of expertise? If as in the Sherlock research, individuals achieve competency faster, the investment may be warranted.

Exploratory Architectures

The exploratory architecture is designed on a premise of high learner control. I include it primarily because it predominates much of the learning opportunities available using the Internet, which is an inherently learner-controlled environment. Figure 3 illustrates an Internet lesson storyboard designed by Chopeta Lyons for IRS customer service representatives. Internet delivery of instruction was indicated since changes in tax laws are sometimes made just weeks before filing season necessitating fast dissemination of updated training. Since the audience is heterogeneous we designed small training sequences at a topic level, which allowed experienced representatives to quickly access just the information they needed. The left navigation frame allows movement among topics at will. Within topics, further control is provided via hot links to pursue or bypass related information. An additional benefit of granularity at the topic level is the potential for repurposing topics for other IRS employees outside of customer service. Within each topic, we used primarily a behavioral strategy with optional interactions and corrective feedback.

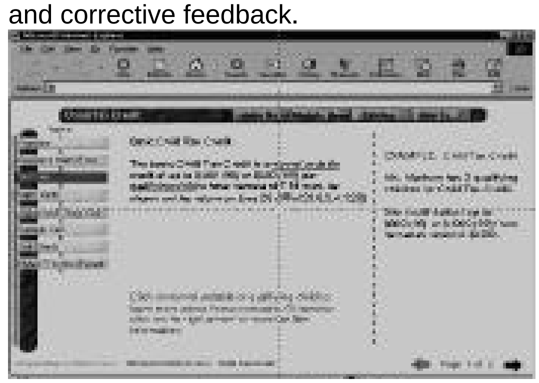

Figure 3. An Exploratory internet lesson on tax law©. (Designed by Chopeta Lyons).

Cognitive Impact

For learning success, exploratory architectures require a combination of good metacognitive skills as well as prior knowledge to enable learners to select those instructional topics and methods needed. Building the instruction in small topics arranged in a bottom up sequence on the menu can help novices acquire the information. Keeping the topics very granular helps manage load in novices and provides "just enough" information for experienced learners. Additional support can be provided via adaptive testing where learner responses are evaluated and instructional advice given.

Cognitive load. Depending on the design and structure of the topics in an exploratory architecture, overload can result. Keeping topics brief and adding frequent optional practice exercise provides an opportunity for load control.

LTM encoding. Opportunities for encoding should be provided for all knowledge and skills that will be new to some or all of the learners. An experienced learner population may be able to encode on their own thus practice opportunities should be optional.

Metacognitive Support. Most Internet users have experienced the "lost in hyperspace" phenomenon. By following several links, learners can easily become disoriented unless some effective navigational techniques are used. A common technique is the use of the left-hand menu frame on the screen such as illustrated in Figure 3. The frame allows the learner to return to a specific lesson or topic at all times. Inherently, most Internet delivered training builds in high amounts of learner control. To make effective decisions about their learning, good metacognitive skills are required. Thus exploratory architectures may be risky for learners who lack background in the material being taught and who lack effective self-regulatory skills. The addition of pretests with advice can compensate for lack of good self-assessment skills in learners.

When to Use

Exploratory architectures are advantageous for learner populations with domain-specific background and experience and good metacognitive skills. If the population is heterogeneous, instructional topics can be kept very small and sequenced bottom up to allow novices a structured sequence and experienced learners flexibility to select their own sequence.

A recent review of the value of hypermedia for instruction (Dillon & Gabbard, 1998) concludes "different students seem to react to this increased control differently, with lower ability students manifesting the greatest difficulty in exploiting it to their advantage. As a general characteristic of hypermedia environments, the ability to control pace and delivery of information, even when coupled with selection advice, appears insufficient to affect learning outcomes significantly for all but high-ability learners" (p. 337).

Exploratory Architectures and the Internet

There is still controversy as to best ways to use the Internet to deliver instruction. Given the high user control features of browsers, an expectation of learner control is brought to any Internet-delivered application. This would tend to favor adapting instruction to the medium and including high control. On the other hand, it is not the media that impact learning; it is the instructional methods. Thus a counterargument can be made that more traditional forms of instruction with minimal learner control could be delivered. As technology increasingly provides greater multimedia delivery options via the Internet, potentially leading to the demise of CDROM, I suggest that training to be delivered via the world wide web be modified to best meet the needs of specific learning populations. In other words, all architectures should be provided based on the performance outcomes and learning audience.

Four Architectures: No Yellow Brick Road

The research on the instructional strategies summarized above reinforces the idea that there is no universal approach to instruction. The four architectures I have depicted vary primarily in:

1. The degree of learner control provided: high to low
2. The organization of instructional topics: bottom up, global based on problems, or learner determined
3. The presence and nature of imposed learner interactions: none, correct responses, problem solving, or optional, and
4. The emphasis on the role of the externally provided instruction versus the internal mental processes of the learner.

In general these variables will interact with learner domain experience, aptitude, and metacognitive skills as well as with the type of outcome sought (e.g. consistent application of procedures or creative adaptations of new skills to ever changing environments and problems). Because of these interactive effects, there are no architectures or methods of universal application to all learners for all performance outcomes. Further, there are rarely pure implementations of a single architecture. Thus for example, guided discovery programs may incorporate a series of behavioral lessons. Or a course that starts with a series of behavioral lessons may end with case studies that incorporate guided discovery.

For many audiences a combination of architectures is ideal. A good example of this is found in a multimedia program developed by Moody Risk Management Services for commercial bank loan agents. As illustrated in Figure 4, the learner starts instruction in the lobby. Entering the left-hand door leads to a learning center including a pretest, a reference library, and a series of lessons designed in a behavioral architecture. Entering the right hand door initiates a guided discovery case study. During the case study, the learner is free to visit the learning center for additional structured lessons. While this approach may combine the best of all architectures, it is relatively expensive and return on investment should be considered.

Figure 4. Combination of Behavioral and Guided Discovery in a multimedia course for bank lenders. Courtesy Moody Risk Management Services®

Summary

Most comprehensive performance improvement programs incorporate some training components. But instructional strategies can vary widely along dimensions of instructional to learner control, organization of instructional units, and emphasis on external instructional elements versus internal cognitive processes. I have attempted to characterize these differences by depicting four architectures, each of which has features that support different learner characteristics and job performance outcomes. I hope this discussion will prompt reflection, research, and dialog about our assumptions when designing training for adult learners in organizations; training that must promote performance improvement in a manner that maximizes return on investment.

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