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TECHNICAL REPORT 95-007

TRAINING DECISION-INTENSIVE TASKS: A CONSTRUCTIVIST APPROACH

NOVEMBER 1995

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TECHNICAL REPORT 95-007

GOVERNMENT RIGHTS IN DATA STATEMENT

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY (Leave Blank)	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
	November 1, 1995	Final Report, 1995

4. TITLE AND SUBTITLE
Training Decision-Intensive Tasks:
A Constructivist Approach

5. FUNDING NUMBERS
PE 0605502N
Contract No. N61339-95-C-0006
Work Unit No. DN 705 101

6. AUTHOR(S)
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8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
Naval Air Warfare Center Training Systems Division
12350 Research Parkway
Orlando, FL 32789

10. SPONSORING/MONITORING AGENCY REPORT NUMBER
NAWCTSD
TR-95-007

11. SUPPLEMENTARY NOTES

12a. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution is unlimited.

12b. DISTRIBUTION CODE

13. ABSTRACT (Maximum 200 words)

Constructivist learning theories represent a new approach to instructional design, and at face value, the constructivist perspective appears to offer an innovative and potentially valuable approach to enhance the effectiveness of Naval training. This report describes the results of a Small Business Innovation Research (SBIR) Phase I study to examine the applicability of constructivist approaches to Naval training. In this report, research is reviewed to identify key concepts that are central to the constructivist approach, examine the application of constructivist approaches to Naval training requirements, and identify high priority research topics and opportunities implied by the constructivist approach. The primary obstacle to realizing the potential value of constructivist applications to Naval training is the fact that very little empirical research has been conducted in a training environment. Research recommendations are made to test the effectiveness of constructivist approaches in a military training setting.

14. SUBJECT TERMS
Training effectiveness, Meta-analysis, Constructivism

15. NUMBER OF PAGES
66

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
Unclassified	Unclassified	Unclassified	Unlimited

NSN 7540-01-280-5500

Standard Form 298 (Rev. 2-89)
Prescribed by ANSI Std 239-18
298-102

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EXECUTIVE SUMMARY

PROBLEM

High technology systems such as the airplane cockpit, the shipboard Combat Information Center (CIC), and other military systems demand critical and effective decision making. These task environments are complex and ambiguous, decision makers must make sense of incomplete and often conflicting information, and the decision maker must respond to changing and often novel situational demands and requirements. Yet, training often takes place in a very simplified classroom setting, decision makers passively learn principles and strategies that are applied to well-defined problems, and training occurs in an environment that is quite different from the real-world setting in which this knowledge will have to be applied. The threat is that this training may result in *inert* knowledge: information that the trainee has in memory, but does not know how to use effectively in the real-world setting.

OBJECTIVE

Constructivist learning theories provide one approach to reduce the gap between knowing information and knowing how to use information in complex task environments. This report describes the results of a Small Business Innovation Research (SBIR) Phase I study to examine the applicability of constructivist approaches to training decision-intensive tasks. In this report, three primary questions are addressed: What is the constructivist approach to training? Are constructivist approaches applicable to Navy training requirements? What research questions must be examined in order to apply constructivist approaches to enhance Navy training?

APPROACH

Research was reviewed to examine the application of constructivist learning theory to training. Separate sections of this report identify key concepts that are central to the constructivist approach, examine the application of constructivist approaches to Naval training requirements, and identify some of the high priority research topics and opportunities implied by the constructivist approach. Finally, a preliminary analysis was conducted to examine one of the instructional strategies implied by the constructivist approach: the role of enhanced context or immersion in training and simulation.

FINDINGS

The constructivist approach emphasizes <u>context</u> in training, or the importance of immersing the learner in a realistic training environment. This principle, which is embraced in recent efforts to develop training in virtual environments, implies that increased trainee immersion will lead to more effective training. However, results of a preliminary meta-analysis

of research on flight simulator training suggest that enhanced immersion may not necessarily lead to more effective training. It is likely that the effect of immersion on training effectiveness may depend on a number of factors, such as the phase of training or the experience level of the trainee. Further research is proposed to examine these questions.

CONCLUSIONS

Constructivist learning theories represent a new approach to instructional design, and at face value, the constructivist perspective appears to offer an innovative and potentially valuable approach to enhance the effectiveness of Naval training. The task environment that is a primary focus of constructivist learning approaches--tasks that are complex, dynamic, ill-structured, knowledge-intensive, and ambiguous--is representative of a wide range of Naval applications. The central concepts implied by the constructivist approach--immersion, cognitive flexibility, active learning, the construction of mental models--are issues that are currently prominent in the military training community. Finally, specific constructivist instructional strategies may lead to innovative and effective approaches to military training, transfer, and performance assessment.

However, the primary obstacle to realizing the potential value of constructivist applications to Naval training is the fact that very little empirical research has been conducted in a training environment. A number of principles and innovative approaches that derive from the constructivist approach have been identified in this report; however, whether these approaches are applicable to Naval training must still be determined. The next step is to conduct empirical research to operationalize these approaches in a military training setting and test their effectiveness in enhancing Naval training.

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INTRODUCTION

THE CONSTRUCTIVIST PERSPECTIVE

Military operational tasks such as aeronautical decision making or shipboard tactical decision making share several characteristics:

- They are very complex and knowledge-rich environments, in that the task environment contains multiple factors that may be relevant to successful task performance. Furthermore, the environmental context (the events that are occurring in the real-world task environment) determines the type of actions that are required. For example, the behavior required given one array of task variables may differ from that required given a somewhat different array of variables. Thus, the task environment is quite complex, and the context is critical to effective performance.

- They are often very ambiguous environments. That is, the task scenarios that are faced on a continuing basis share broad similarities, but there is a considerable amount of case-to-case irregularity. Rarely does the decision maker face the same problem over and over, but instead faces task environments that are novel or contain ambiguous or conflicting information.

- Decision makers are not passive, but must actively make sense of complex and often conflicting information.

- The task situation is dynamic, and performance must respond to changing situational demands and requirements.

This type of decision making environment presents a number of problems for the training designer. Can skills be trained outside of the context in which they are applied? How can the trainer ensure that knowledge gained in training is transferred to the real-world setting? How can trainees be taught the flexibility to apply knowledge to novel cases?

Designing training programs to prepare individuals for the decision intensive tasks associated with these environments continues to be a significant challenge. Many argue that the constructivist approach to instruction provides an innovative perspective for training complex tasks. It may be useful to provide a broad distinction between the traditional, <u>objectivist</u> approach to instruction and <u>constructivism</u>. Traditional instructional design has evolved from a objectivist perspective. Objectivism holds that knowledge resides in the external object, independent of individual experience. One gains understanding by coming to know the external objects and relations that exist in the external world. Instruction is organized to identify the objects and relations the learner must know, present the relevant facts and principles, and provide practice to gain mastery of this knowledge. Therefore, the goal of instruction is to help the trainee acquire the basic information and routines needed for effective performance. This objectivist position underlies not only the traditional instructional design practices of the past 20 years, but also the modern "information-processing" view of performance. Knowledge is seen as composed of production rules exemplified in an expert model, and learning is primarily a matter of learning appropriate production rules.

Navy training programs, in general, embrace the objectivist approach to design: Training objectives are defined based upon the skills and knowledge required to perform job tasks; appropriate training media are identified; and the trainee is then provided with a systematic program to acquire the necessary enabling skills and knowledge that will enable the job task (the terminal training objective) to be performed to the standard identified. In the process, the trainee is given opportunities to practice and then demonstrate mastery of the skills and knowledge that have been acquired. Performance assessment stands separate from the instruction and is intended to assess the knowledge acquired in an "objective" manner. This systematic process, sometimes referred to as the Systems Approach to Training (SAT) or more commonly, Instructional Systems Design (ISD) is adhered to in nearly all Navy training programs. Instructional delivery systems such as computer based instruction follow this objectivist tradition in the frequent use of instructional strategies such as drill and practice or tutorial. From shore-based formal school programs to unit level OJT, the emphasis in most Navy programs is on presenting facts and principles and giving the trainee the opportunity to learn and practice the production rules necessary to perform their job.

Constructivism provides an alternative perspective of how individuals learn. The constructivist approach is a consequence of the emphasis in cognitive psychology on individual representation of external events. Jonassen (1991) provides a distinction between the assumptions in objectivism and constructivism. The objectivist sees reality as external to the knower with mind action as a processor of input from reality. Meaning is derived from the structure of reality with the mind processing symbolic representations of reality. The constructivist, on the other hand, sees reality as determined by the experiences of the knower. The constructivists argue that meaning does not exist in the external object, but that individuals actively impose meaning on events. Learning is a constructive process in which the trainee builds (or constructs) an internal representation of knowledge that is based on experience. This experience is gained through active problem solving in real-world contexts.

A key component of the constructivists' position is the emphasis on teaching not just information, but how to use that information in real-world settings. Constructivists argue that much of standard instructional design practice centers around designs that teach plans of action, and the student's task is to learn to follow these plans. However, a critical aspect of performance in the real-world is the ability to respond to changing situational constraints -- to be able to construct new plans, strategies, and behaviors in response to novel or complex task environments. The constructivists maintain that instruction should not focus on transmitting plans of action, but on developing the skills in the learner to allow that person to construct effective plans in response to changing situational demands.

Constructivist learning theory postulates that instruction should be presented in meaningful contexts and with multiple practice opportunities that will aid the learner in making sense of the environment as it is encountered and changes. With sufficient representation established, the learner can make use of acquired knowledge in a variety of contexts. Constructivists suggest that the ready recall of information and smooth execution of procedures does not guarantee active use of knowledge or skills, as the learner later strives to cope with novel situations. Learning is seen as an active process that should be situated or anchored in a real world context to be effective. Through collaborative efforts, the individual's representation of knowledge may change as additional perspectives are gained. In this manner, conceptual growth occurs. Constructivists believe that instructional activities that reflect these assumptions have a far greater chance of transferring from the learning environment to real world situations.

A growing number of learning theorists have embraced constructivism as an approach to instructional design that places greater emphasis on the role of cognition in learning. Some of the central concepts that reflect the constructivist perspective follow.

Meaning is indexed by experience (Brown, Collins, & Duguid, 1989a). The experience in which an idea is embedded is critical to the individual's understanding of and ability to use that idea. In this respect, each experience must be examined to understand the learning that occurs.

The learner must be "genuinely engaged in and reflecting upon authentic exploration of the subject matter" (Brown, Collins, & Duguid, 1989b). The more authentic the subject matter and the greater the extent to which the subject matter has genuine meaning for the learner, the greater the degree of learning that takes place.

Context is an integral part of meaning (Spiro, 1980). If the learner focuses on only the critical features of a concept, he or she will have a limited, textbook understanding. On the other hand, aiding the learner in working with the concept in a realistic environment will help the learner see the complex interrelationships and dependencies that exist.

Central to learning is the notion of the organism as "active" (Perkins, 1991). Active implies more that just responding to stimuli, as in the behaviorist rubric, but engaging, grappling, and seeking to make sense of things.

Skills cannot be considered independently of the problems to which they are applied (Cunningham, 1991). Mastering a specific subskill means using it effectively in solving problems.

Learning is a collaborative process (Cunningham, 1991). Meaning is derived from a number of perspectives. Conceptual growth comes from the sharing of multiple perspectives and simultaneous changing of our internal representations in response to those perspectives.

Effective learning is generative (Resnick & Resnick, 1993). A learner gauges his or her understanding of the substasks by the successful completion of the larger goal, not by a decontextualized standard.

Effective learning experiences are "anchored" (Cognition and Technology Group at Vanderbilt, 1990, 1991a). A major goal of the constructivist approach is to create shared environments that permit sustained exploration by the learner and enable the learner to understand the kinds of problems and opportunities that experts in various areas encounter and the knowledge that these experts use as tools.

The emphasis for learning should be on the flexible use of pre-existing knowledge rather than the recall of prepackaged schemas (Spiro et al., 1991). Mental models developed through task engagement are likely to increase the efficiency with which subsequent tasks are performed to the extent that parts of the environment remain the same.

FROM BEHAVIORISM TO COGNITIVISM TO CONSTRUCTIVISM

It is useful to briefly examine the paradigm shifts in instructional design practices over the past several decades to better understand constructivism and the emerging interest in this approach to training design. For more than 20 years, learning psychology has shifted from a behavioristic view toward a cognitive perspective (Greer & Verschaffel, 1990). Jonassen (1990) notes that it has taken a number of years for instructional design as an applied discipline to recognize the need for seriously considering a shift in theory as well as in practice.

Lamos (1984) describes the beginnings of the instructional design movement as centering around B.F. Skinner and programmed instruction. This approach to instruction was behaviorally based and characterized by three stages: (a) analysis, (b) design, and (c) evaluation. These stages map to the general scientific approach (hypothesis generation, experimental design, and hypothesis testing). The analysis stage of instruction, typically constructed as behavioral objectives with criterion-referenced tests as the vehicle for assessment, leads to a required performance and to a great extent the elimination of peripheral knowledge acquisition. The goal of this objectivist approach to instructional design was to make instruction more controllable, efficient and effective by applying behaviorist principles. The appeal of a systematic approach was embraced heavily by military training organizations seeking to establish a consistent, focused and efficient methodology to ensure that all training requirements were addressed during the conduct of training. An early assumption of this approach was that knowledge-of-results feedback provided reinforcement. As the objectivist approach matured, this view gave way to a more complex concept that whereas learning increases the likelihood of target behaviors being exhibited by the learner, the primary reinforcers are considered to be learner generated ("intrinsic"), and that external feedback ("extrinsic") is most effective as either correctional or motivational feedback (Bullock, 1982).

Interest in the role of cognition in learning lead to an awareness that the content of instructional design models had to be changed. However, difficulties in the applicability and scope of traditional instructional design models has hindered integration of more cognitive aspects (Lowyck, 1988). Most traditional instructional design models, such as the Systems Approach to Training (SAT) or Instructional Systems Design (ISD) aim at controlling specific learning outcomes by offering a methodology that will increase the probability that particular kinds of learning outcomes will appear. In this respect, a key feature of traditional instructional design models is their controlling, rather than their enabling nature (Lowyck & Elen, 1993). Merrill, Li, and Jones (1990) identified some limitations of the "first generation of instructional design". These were summarized by Lowyck and Elen as follows:

- Limited attention for integrated wholes in content analysis, course organization and teaching
- Limited prescriptions for knowledge acquisition
- Closed and inflexible systems
- Instructional development remains separated from instructional design
- Instruction prescribed is often passive rather than interactive, it primarily focuses on presentation variables
- Instructional design is labor intensive

As the behaviorists' ground gave way in the past two to three decades, the need to encompass individual differences emerged and brought with it an increased complexity of instructional design. For example, the analysis phase of traditional instructional design now had to accommodate the evaluation of individual learner requirements and capabilities, including different types of learning styles and the ability to apply cognitive strategies. Some means for conducting task analysis that considers cognitive analysis rather than procedural decomposition solely had to be developed. Central to cognitive analysis is a model of the internal working of the mind, the identification of functional components to handle information filtering, storage in short term memory, and retrieval when required (Cooper, 1993). With regard to the role of memory, cognitivism emphasizes the storage of information in an optimal, meaningful way. Instructional designers and instructors are responsible for assisting learners in organizing this information in meaningful ways. Military supported instructional design models such as ISD and SAT do not currently support cognitively based activities. However, work by Merrill, Li and

Jones (1990) on second generation instructional design (ID_2) incorporates cognitive theory into instructional design models.

Recently, a number of cognitive theorists have begun to question the objectivist assumptions regarding learning (Ertmer & Newby, 1993). In contrast to behaviorism and cognitivism, constructivism offers a fundamentally different view of learning in that both behaviorism and cognitivism see reality as external to the knower with the mind acting as a processor of input from reality. Meaning is derived from the structure of reality. The constructivist, however, sees reality as determined by the experience of the knower (Jonassen, 1991). Cooper (1993) summarizes the relationship between the three design approaches.

> "To the behaviorist, the internal processing is of no interest; to the cognitivist, the internal processing is only of importance to the extent to which it explains how external reality is understood. In contrast, the constructivist views the mind as builder of symbols -- the tools used to represent the knower's reality. External phenomena are meaningless except as the mind perceives them. Constructivists view reality as personally constructed, and state that personal experiences determine reality, and not the other way around" (p. 16).

Table 1 provides a comparison of the three learning theories (see Ertmer and Newby, 1993).

Table 1
Comparison of Behaviorist, Cognitivist and Constructivist Approaches to Learning

Approach	**Behaviorist**	**Cognitivist**	**Constructivist**
How Learning Occurs	Learning takes place when an appropriate response is demonstrated following the presentation of a specific environmental stimulus.	Mental activity that involves internal coding and structuring by the learner.	Learner creates meaning from experience as opposed to acquiring it. Mind filters input from the world to create its own unique reality.

Table 1 (Continued)
Comparison of Behaviorist, Cognitivist and Constructivist Approaches to Learning

Approach	**Behaviorist**	**Cognitivist**	**Constructivist**
Factors Influencing Learning	Environmental factors receive the greatest emphasis.	Environmental conditions, practice with corrective feedback, mental activities of learner that lead up to a response.	Both learner and environmental factors are critical as is the interaction between the two. Behavior is situationally determined. Learning occurs in realistic settings. Selected learning tasks. need to be relevant to learner's lived experiences.
Role of Memory	Not addressed. Habits are addressed but given little attention on how they are stored for future use.	Prominent - learning results when information is stored in memory in an organized, meaningful manner.	Always under "construction" as a cumulative history of interactions.
How Transfer Occurs	Situations involving identical or similar features allow behaviors to transfer across common elements.	Function of how information is stored in memory. Transfer occurs when learner understands how to apply knowledge in a different context.	Facilitated by involvement in authentic tasks anchored in meaningful contexts.
Types of Learning Best Explained by Theory	Recalling facts, defining and illustrating concepts, applying explanations, automatically performing a specified procedure.	Complex forms of learning (reasoning, problem solving, information processing).	Advanced knowledge acquisition, complex and ill-structured problems.

Table 1 (Continued)
Comparison of Behaviorist, Cognitivist and Constructivist Approaches to Learning

Approach	**Behaviorist**	**Cognitivist**	**Constructivist**
How Instruction Should be Structured	Should be structured around presentation of the target stimulus and the provision of opportunities for the learner to practice making the proper response.	Instructors should arrange environmental conditions so students respond properly to the presented stimulus, make learning meaningful, and help learners organize and relate new information to existing knowledge in memory.	Should be structured to show the learner how to construct meaning as well as how to evaluate and update constructions. Should align and design experiences for the learner so that authentic, relevant contexts can be experienced.

A constructivist view of the continuum of knowledge acquisition that progresses from ignorance to expertise has been offered by Jonassen (1992). The learning phases that reflect knowledge growth are introductory, advanced, and expert. Table 2 depicts this continuum. According to Jonassen, introductory learning occurs when learners have little prerequisite knowledge about a skill or content area that will transfer. The second phase is advanced knowledge acquisition. During this phase, the learner acquires more advanced knowledge that allows him or her to solve more complex, domain or context dependent problems. The final phase of knowledge acquisition is expertise. Experts can be characterized as having richly interconnected knowledge structures. They are able to approach problems in a way that allows problem solution to be more efficient. According to Jonassen, the expert's approach to solving problems as well as the automaticity of their responses are not necessarily a result of instruction or training. Expertise results from extensive experience that requires broad transfer of knowledge that has been acquired during previous phases of learning.

Constructivists suggest that classical instructional design approaches, based upon predetermined learning outcomes, constrained and sequential instructional interactions, and criterion-referenced evaluation, are more appropriate for initial knowledge acquisition. Constructivist approaches are appropriate during the latter stages of initial knowledge acquisition, but are better suited for application during the advanced knowledge acquisition

Table 2
Knowledge Acquisition as a Function of Phase of Learning

Phase of Learning	Introductory	Advanced	Expert
Type of Problems Addressed	Well Structured Domains (Skill-Based)	Ill-Structured Domains (Knowledge-Based)	Elaborate Structures (Interconnected Knowledge)
Training Objective	Initial Knowledge Acquisition	Advanced Knowledge Acquisition	Expertise
Training Approaches	Practice, Feedback	Apprenticeship, Coaching	Experience

phase. Jonassen argues that since expertise is the result of situated experiences, expertise will be fostered by rich levels of instructional activities in constructivist environments.

In the following chapters, we examine the application of constructivist learning theory to training. In Chapter 2, we identify key concepts that are central to the constructivist approach. Chapter 3 examines the application of constructivist approaches to Naval training requirements. Chapter 4 identifies some of the high priority research topics and opportunities implied by the constructivist approach.

CONSTRUCTIVISM: KEY CONCEPTS

In the following, we examine some of the key concepts implied by the constructivist approach. The goal of this chapter is to address two questions: (a) How does the constructivist approach differ from traditional instructional design? and (b) What type of unique opportunities or perspectives does the constructivist approach offer that may be applicable to Naval training? We will examine key constructivist concepts in three areas: training, learning transfer, and assessment.

TRAINING

Training Cognitive Flexibility

Recent Naval research has focused on the training of aircrew coordination skills that determine effective decision making and flight safety. These programs, such as the Aircrew Coordination Training (ACT) program developed by the Navy and other Crew Resource Management (CRM) training programs in the civilian community, emphasize training activities to improve skills in domains such as communication, situational awareness, leadership, and adaptability/flexibility. By addressing these skills in the context of the specific task environment, the goal is to ensure an appropriate set of behaviors will be exhibited and thus enhance effectiveness of job performance. Typically, these programs rely on classroom instruction to present pertinent concepts followed by situated practice activities and feedback where trained instructors or evaluators observe the presence or absence of specific behaviors.

One approach to training decision making directly has utilized models that prescribe a structured process that the team should use to carefully consider alternatives and consequences before acting. The DECIDE model (see Jensen, 1989) is one example of a number of structured approaches. This model incorporates six steps: Detect, Estimate, Choose, Identify, Do, and Evaluate. Although Jensen found that pilots trained in the use of the model made safer and more systematic decisions in simulated flight scenarios, the value of this type of static approach is questionable for more dynamic environments where high demand and ambiguity is the norm. Unfortunately, some training strategies often work effectively in the training setting but more poorly under operational conditions (Schneider, 1984).

Traditional instructional design has placed an emphasis on learning prepackaged modules--for example, the trainee may first learn principles of communication, then leadership, then situational awareness, and so on. However, the real world task environment is often complex, ill-structured, and ambiguous. Rarely are these knowledge domains encountered in as "pure" a form as they are presented in the training setting (that is, these elements are interrelated in complex ways in the real world task environment). And rarely does the trainee face a situation in the real world exactly like that addressed in training (that is, the real world environment, whether it is Three Mile Island or an F-14, presents situations that are ambiguous, unexpected, and difficult to predict beforehand). Thus, the presentation of prepackaged modules and principles may lead to an oversimplification of a complex task environment, and result in lack of transfer of information from the training setting to the real world.

The constructivists maintain that because knowledge will have to be used in too many ways in the real-world environment for these situations to be anticipated in training, the training emphasis should shift from learning set plans of action or schemas (such as a DECIDE procedure) to an emphasis on how to construct plans, strategies, and behaviors in response to novel or complex task environments. In brief, because complex task environments contain too many interdependent elements to allow the trainee to apply preexisting principles, the constructivist approach places a strong emphasis on training the cognitive flexibility to apply knowledge to novel settings. Accordingly, instructional experiences such as computer-based simulations should be presented with the full context and complexity of the real world. The process of solving problems in this setting from various perspectives and in different scenarios should allow the trainee to understand the interrelatedness of complex task elements and develop the flexibility to transfer the knowledge gained to novel settings that may be faced in the future.

Fostering complex conceptual understanding and adaptive knowledge that will transfer from one context to the next is a key consideration for training decision intensive tasks. Cognitive Flexibility Theory (Spiro et al., 1988) is a constructivist approach aimed at promoting the flexible use of knowledge, i.e., from one context/situation/case to the next. Spiro et al. (1991) refer to cognitive flexibility theory as a "new constructivist" response to the difficulties of advanced knowledge acquisition in ill-structured domains. An ill-structured domain is defined by two properties:

- Each case or example of knowledge application typically involves the simultaneous interactive involvement of multiple, wide application conceptual structures, each of which is individually complex, and;
- The pattern of conceptual incidence and interaction varies substantially across cases that are nominally of the same type.

Spiro argues that all domains that involve the application of knowledge to unconstrained, naturally occurring situations (such as cases) are substantially ill-structured. In introductory learning, ill-structuredness is not a serious problem. The learner is not expected to master complexity or transfer acquired knowledge to new situations. Mastering complexity and transferring acquired knowledge to new situations becomes critical only when the learner must apply the basic knowledge to increasingly complex treatments of the same subject matter.

Consistent with the constructivist approach, cognitive flexibility theory stresses the importance of presenting or revisiting the same material (or training activity) at different times in rearranged contexts, for different purposes, and from different conceptual perspectives (Spiro & Jehng, 1990). The goal of this process is to prepare the acquired knowledge for transfer to new and unique situations. This concept of "multiple representations" is particularly important in that the complexity of some operational environments requires that training be presented from multiple perspectives or in multiple contexts. Spiro argues that if particular learning requirements are treated too narrowly by presenting them using a too limited subset of their relevant perspectives (contexts), the ability to process future cases will be limited. According to Spiro, the learner will first make the assumption that cases are simpler than they actually are and will attempt to solve new cases by prematurely making a conclusion after information has been only partially analyzed. Second, there will be a lack of preparedness to deal with the specific patterns of interaction within cases. Third, to the extent that performance in subsequent cases will require application of prior knowledge, the degree to which cases are represented narrowly in memory will lessen transfer to subsequent cases or applications. However, the problem of how to provide multiple representations in training presents a considerable difficulty for the training developer. The development of tools to assist the scenario developer in this task is one area that requires further research (see Chapter 4).

The Constructivist Emphasis on Active Simulation

From an objectivist instructional perspective, knowledge should be simplified or broken down into simple building blocks for instruction (in fact, one goal of the traditional task analysis procedure is to identify the basic components of knowledge). Knowledge is seen as most efficiently transferred if it is presented in its most simple, atomistic form, devoid of context. The constructivists voice an objection to breaking knowledge up into isolated units removed from context. For example, the constructivists may argue that principles of "decision making flexibility" should not be taught as an isolated concept, but that flexibility must be understood in terms of how it relates to the larger decision making environment. Constructivists argue that the traditional objectivist perspective leads to a segregation of knowledge; that is, we may learn concepts and relations in the training setting that are quite different from how we may experience or apply them in the real world. This leads to "inert" knowledge, or information that the trainee has available in memory, but may not be able to use or apply to new environments.

By contrast, the constructivists emphasize learning in context. Learning must be situated in a rich context, reflective of the real-world context. Therefore, the environmental context is critical, and constructivists argue that we must not simplify learning environments as is often done in the classroom, but we must maintain the complexity of the environment. Thus, the environmental context provides the link between knowledge and the use of that knowledge in real-world settings. Perkins (1991) notes that the basic goals of instruction are retention, understanding, and active use of knowledge. Therefore, attaining active use of information (versus inert knowledge) is one of the primary goals of the constructivist approach. Active use implies the ability to independently use knowledge in new situations that differ from the conditions of initial instruction.

The constructivist emphasis on learning in context leads to a strong reliance on the use of active, dynamic simulations to train complex skills. Continuing technological advances in computer processing power and Object Oriented Design (OOD) programming techniques has fostered a significant interest in exploring the use of simulation as a constructivist learning strategy. In a simulation, all variables are closely tied to one another, they mutually affect each other, and constitute a network of interdependencies. The participants in a computer-based simulation gather information at certain points in time, make decisions, and take necessary actions. They are then confronted with the effect of their decisions, are able to gather further data, decide on the same or different actions, and so on. By observing the effects of their actions, participants are able to learn cause-effect relationships and better understand the interdependencies between related variables.

Dorner (1990) has used simulation to study the realm of complex decision making. In his research, Dorner found that subjects often failed to construct an adequate picture of a complex, interconnected system. That is, subjects often did not treat a system as if it were an integrated system, but rather perceived it like an accumulation of disconnected variables that could be manipulated in isolation. Because of this lack of understanding of how variables are interdependent, subjects tended to be unaware of the long term effects and side effects of their decisions. Dorner found that subjects were more likely to develop an overall picture of the relevant variables that impact decision making through the use of dynamic simulations. Furthermore, by using computer based simulation as a training strategy, subjects were better able to recognize and internalize complex interdependencies. For Dorner's research, a computer based simulation, functionally similar to commercially available simulations such as SimCity or SimEarth was used. Dorner concluded that this type of instructional approach may be particularly effective for tasks that involve many indefinite and unpredictable variables.

Platt and Guynn (1994) have identified several general simulation strategies. A number of these strategies reflect a constructivist orientation. These simulation types include:

- Active Interactive Simulation. This strategy centers around an object or entity which provides information to the learner. The learner, in turn, is able to perform various procedures and receive feedback that models the system or operational equipment. A full motion simulator would be an example of this simulation strategy.

- Database Access Discovery Learning. This strategy includes a relational database that the user can query for information on a random basis. The strength of this approach depends upon the learner identifying and learning patterns and relationships that are inherent within the data. These data are then integrated into a learner "constructed" framework. Learners may use this approach as part of solving a problem or task that depends upon the data in the database.
- Scenario Driven Free-Play with Active Instructor Coaching. This strategy blends simulation with a variation of cognitive apprenticeship. In this approach, a simulation of a situation may be coupled with an event driven scenario that presents opportunities to practice task interactions under various situations such as emergencies, system failures, or routine operations under various degrees of stress. The learner is free to take action in relation to the events. An instructor functioning like a coach provides feedback and guidance at his or her discretion. On-line or context sensitive help may be used in lieu of instructor guidance.
- Scenario Driven Free-Play with Computer Generated Feedback. In this variation of the previous strategy, the computer is programmed to provide feedback, including error messages, as a response to certain actions or inactions on the part of the learner.
- Opposing Force Game with Active Instructor Coaching. With this approach, the instructor can counter the learner's actions to illustrate some aspect of the task being learned. This strategy might be used to help the learner better understand the dynamics or interrelationships of a complex system such as weapons employment in various tactical situations and conditions.
- Opposing Force Game with Computer Generated Feedback. This strategy is similar to the previous strategy except that the computer is programmed to respond or counter the learner actions in order for the learner to acquire knowledge of specific relationships.

Mental Models

The constructivist position places a strong emphasis on the organization of knowledge into mental models, which are constructed by the learner on the basis of experience. A central tenet of the constructivist approach is the notion of the learner as active--not just a passive recipient of information, but an active processor of information that elaborates, interprets, and makes sense of information. As such, learners do not simply store information in memory, but make tentative interpretations of experience and modify and test these interpretations. In this manner, knowledge is constructed: candidate mental models are formed, elaborated, and tested as the learner gains experience with the task environment.

Thus, the constructivist position represents a shift from the traditional objectivist approach that emphasizes the retrieval from memory of pre-existing knowledge to a position that emphasizes the construction of knowledge and the flexibility of knowledge structures or mental models. In fact, the constructivists caution against providing trainees with static plans of action to be followed in the task environment. A critical aspect of performance in complex task environments is the capacity to respond to changing situational constraints, or to novel or ambiguous circumstances. Instead of transmitting plans of action to the learner, the constructivists argue that the emphasis should be on developing skills in the learner that will allow that person to construct plans of action in response to changing task contingencies.

Accordingly, a key goal of instruction is to develop cognitive flexibility. That is, the emphasis is to provide the learner with a flexible mental model developed from different perspectives that will allow the learner, when faced with a novel task environment, to reassemble information from preexisting knowledge that will adaptively fit the requirements of the new situation. This cognitive flexibility requires flexible learning environments. Spiro et al. (1992) note that "knowledge that will have to be used in a large number of ways has to be organized, taught, and mentally represented in many different ways" (p. 66). Merrill (1992) notes that mental models cannot be simply transferred into the heads of trainees, but that trainees must be actively involved in constructing knowledge, or building a mental model of complex phenomena. Again, the constructivist emphasis is on the development of active computer-based simulations, in which the learner can attain an understanding of the interrelated elements that comprise a complex task environment.

Problem Solving in Ill-Structured or Complex Domains

Constructivists argue that the presentation of a core set of plans of action or principles to be applied in a task environment leads the learner to oversimplify what is in fact a very complex environment. They propose that rather than simplify training material, the trainee should learn to solve problems in a full-context, realistic task representation. Cognitive flexibility is developed as the trainee learns to solve problems in scenarios that are presented from a number of differing perspectives and examples. However, what strategies can be developed to aid the trainee to manage this complexity? Cognitive apprenticeship has emerged as one approach that incorporates many of the constructivist learning activities. In the following sections we will examine the concept of cognitive apprenticeship as well as several related instructional strategies for dealing with ill-structured domains, including the guided generation model, the Leittext method, and problem-oriented learning.

Cognitive Apprenticeship. Cognitive apprenticeship methods attempt to engage the learner in authentic practices in a manner similar to that used in craft apprenticeship. The goal is to go beyond simply giving the learner strategies to solve problems (or make decisions) but to foster an environment that immerses the learner in a problem solving or decision making culture. The result is that the learner has the opportunity to model the thinking of an expert as well as learn to utilize available resources and tools to solve the problems inherent in the task environment. While many current aviation training programs attempt to use realistic practices such as flight scenarios in part-task and full motion simulators, the opportunities to learn and model the decision making thought processes of an expert are limited or non-existent. Typically, the instructor provides a snapshot of what was done well or poorly. In the complex realm of decision making skills, the extent to which the learner has the opportunity to construct or internalize principles and interrelationships may have a significant bearing upon what skills and knowledge transfer to new situations not addressed during training.

Three procedures characterize cognitive apprenticeship. For training decision intensive tasks, these might be adapted as follows:

- The utilization of learning tasks embedded in familiar activities. This legitimizes the learner's implicit knowledge and its availability as scaffolding to provide a link to unique tasks or situations.
- Guided practice using expert modeling for the decomposition of various decision making tasks and events. This practice should stress that heuristics are not absolute but must be assessed with respect to each situation.
- Allowing the learner to generate and test his or her own solution paths. This will foster the learners' participation as conscious, intuitive decision makers. Through this process, they will acquire the decision making culture's tools, vocabulary and means to discuss, reflect upon, evaluate and validate procedures in a collaborative process.

Several other researchers have offered related instructional strategies that contain elements that are similar to cognitive apprenticeship. Palincsar and Brown (1984) designate their approach to learning as reciprocal teaching. Schoenfeld (1985) has emphasized a cognitive coaching strategy. Finally, Scardamalia et al. (1984) propose the use of a direct explanation method.

Structured Problem Solving and The Guided Generation Model. The Cognition and Technology Group at Vanderbilt (CTGV) (1993) has identified several models of instruction for fostering problem solving skills that are constructivist oriented. Structured Problem Solving is used to focus on reducing learner errors and a sense of confusion when solving problems. In this model, the instructor provides the learner with a set of possible solution sets. The learner is then guided through the process of evaluating these plans. In theory, the greater the degree of guidance, the higher the probability that the student will not make errors. Anecdotal data suggest that this model is beneficial for ensuring that the learner works on correct problem solving strategies. The trade-off is that the learner does not engage as deeply in problem generation and monitoring.

The CTGV researchers note that an essential part of problem solving is the ability to generate sub-goals necessary to achieve one's objectives. The Guided Generation Model emphasizes the importance of generative activities on the part of the learner. According to CTGV, meaningful generation usually occurs in relatively complex situations where the sub-goals necessary for problem solution are not pre-specified. One of the goals of this instructional strategy is to facilitate problem finding as well as problem solving. In this model, the instructor may provide some guidance, but typically adopts the role of a learner. The instructor does not provide solutions, but can guide the learner as necessary to arrive at solutions.

The Leittext Method. Simons (1993) has examined several learning environments which strive to induce constructivist learning. The Leittext Method grew out of the West German industrial sector as a response to the demands for flexibility and independence in workers. This method emphasizes independent work and problem solving. This is achieved by creating a structure for independent learning without allowing the learner to encounter too many problems or stray too far from the goals or objective designated by the instructors. Several learning phases are used for the method. The preparatory phase of learning or problem solving is very highly structured. Initially, the learner is informed about the project, its characteristics, what it will look like when completed, principles to use for developing the project and why it is important. Steering and information questions are used along with planning aids and control lists. In the next phase, the instructor guides the student in planning how to proceed. The recall of prior information or transfer of knowledge from previous learning is activated through questions. The learner controls the third phase which is the actual development. In the final phase, the instructor and student evaluate not only the results, but the whole process of learning that occurred. Once the learner becomes familiar with the method, he or she may assume greater control during the planning phase. Simon notes that it is not clear what this method primarily addresses - learning or self regulation. Published applications of the Leittext method apply to non-authentic situations that have little to do with real world job tasks. However, the method may have some influence on the way learners approach problems and how they proceed when learning independently.

Problem-Oriented Learning. Problem Oriented Learning has evolved as a response to training in ill-structured domains such as professional medical education and the social sciences (see Simons, 1993). Several distinct phases characterize this approach to learning: problem discussion, analysis, hypothesis generation, finding knowledge gaps, deciding on individual learning goals, individual study, and synthesis. Initially, the student gets a written description of the problem, e.g., a case study, or a scenario. The learner's task is not to solve the problem but to analyze it and to generate as many hypotheses as possible to explain the symptoms. In addition, learners need to discover what they already know about these explanations and what are their knowledge gaps. The learners must then define their individual or group learning goals. That is, what should be learned from the problem and its possible explanations? Intensive evaluation of facts and other related information follows. A subject matter expert is available to answer questions or guide the learning process. Data collected by each individual are then discussed in group settings. The original problem is analyzed once again in light of the additional group data and observations in order to formulate conclusions. Periodically, performance evaluations are conducted related to subject matter knowledge and skills. As with the Leittext method, the emphasis is on the preparatory phase of learning. The problems define how the learner is oriented to acquire the related skills and knowledge. In the problem-oriented approach, the problems are written in such a manner that there is a close link to real-world applications. Whether solving the problems as individuals or as a group, the learner is activated to recall knowledge and skills related to the problem and its possible explanation. Simons (1993) notes that this method does not attempt to improve problem solving or thinking skills in a direct way, but because of the direct connection of the learning objectives to the problems to be solved, improving problem solving skills may be a by-product.

Collaborative Learning

The constructivist approach stresses that the learner should be exposed to multiple perspectives on an issue. Bednar et al. (1992) suggest establishing a collaborative instructional environment as a means for developing multiple perspectives. This approach is not to be confused with cooperative learning, in that task sharing or establishing team consensus is not a goal of collaboration. Collaborative learning involves developing and weighing the merits of alternative views in order to develop, compare, and understand multiple perspectives on an issue or decision. This process goes beyond sharing--the learner's goal is to search for and evaluate evidence that supports various viewpoints. Bednar envisions the process as cooperative rather than as competitive with each learner coming to understand each perspective and even contributing to the development of each perspective.

The objective is to see an issue from different vantage points and understand the alternative decisions and actions present. Bednar et al. (1992) suggest that the learner can then evaluate each perspective and identify strengths or weaknesses of alternatives. From this evaluation and sorting out process, the learner will adopt a perspective that is the most meaningful and relevant to them in the particular context. Jonassen et al. (1993) suggest a case (scenario) based approach for achieving multiple perspectives. In order to adapt the process to training events, a hypertext format might be used. With this strategy, the learner must determine the information needed to make a decision or take a specific action. He or she has the option of accessing information from various sources including various texts or databases. The learner can also query various subject matter experts for alternative perspectives. Each of these information sources provides a separate point of view that the learner can trade-off against the specific events. The hypertext format greatly reduces oversimplifying instruction, provides the multiple representations required, situates the knowledge being learned in a specific context, and fosters knowledge construction rather than simple transmission between an instructor and the learner.

Brown, Collins and Duguid (1989a) identify several characteristics of the learning environment that support the concept of collaborative learning. These might be adapted in the following manner for training:

- Collective problem solving. Groups are more than a convenient way to build the knowledge of individuals. Groups foster a synergy that can bring about new insights and solutions that may normally not come about from individual problem solving.
- Displaying multiple roles. Successful performance of most individual tasks requires the learner to understand the many different roles needed for accomplishing any cognitive task. Group training activities can allow different roles to be displayed and permits narratives such as "war stories" to add to the collective wisdom of the particular group.
- Confronting ineffective strategies and misconceptions. A number of researchers have remarked about learner misconceptions in complex learning environments (e.g., diSessa, 1982, 1983, 1986; White, 1983). Instructors often lack the opportunities or settings to recognize that a learner is providing only surface retelling of information and could be masking misconceptions about the content area and problem solving strategies. Groups may be an effective mechanism for drawing out, confronting, and discussing misconceptions and ineffective strategies.
- Providing collaborative work skills. Trainees who are taught individually rather than in a team environment can fail to develop skills needed for collaborative work. In increasingly complex environments where teams skills must be displayed, opportunities to learn collaboratively will become increasingly important.

Situated Cognition and Authentic Activities

Traditional instructional design theory is based on the assumption that the learner will solve problems using the same logic that task analysis uses to break them apart (Winn, 1993). The assumption is that the learner will apply the same logical structure in a procedure or task hierarchy that the designer does. However, for example, a pilot may misdiagnose an engine malfunction in a critical situation by considering only the obvious or "trained for" symptoms rather than by applying system knowledge to determine less obvious causes of the malfunction. Recent research by Brown et al. (1989a), Lave (1988), and Suchman (1987) indicates that individuals often do not solve problems directly by using the kinds of problem solving skills they have been formally taught, but by using the materials and information that they find in the context in which the problem presents itself. For example, Streibel (1989) found that learners do not use formal academic logic for solving real world problems.

Situated cognition as a constructivist learning approach seeks to situate knowledge and learning in coherent, meaningful, and purposeful activities and thus enhance the probability that knowledge learned in one setting will be skillfully or even creatively applied in another setting. Constructivists speak of "authentic activities" as a means to situate learning. Brown, Collins, Duguid (1989a), in their pioneering article on situated cognition, argue the importance of authentic activity. They believe that only authentic activities can shape and hone learning skills. Brown et al. (1989a) define authentic activities as the practice of the culture; that is, authentic activities include the activities, the jargon, and the behaviors that make up a particular task environment. Spiro et al. (1991) suggest that the more complex or ill-structured the training requirement, the greater the emphasis that is required on authenticity in the training environment in order to foster transfer from one context to another. Thus, for simpler tasks, authenticity may be less critical. For example, fault isolating a basic power supply problem can be taught in a lab environment with a simple trainer or interactive courseware. For this simple task, the extent to which the training environment is considered "authentic" (compared to the actual equipment or job setting) most likely will be of limited concern for successful job performance. On the other hand, a more complex or ill-structured task, such as recognizing the subtle and conflicting symptoms of a helicopter high side engine failure and dealing with that emergency, will require a greater consideration of the authenticity of training.

Honebein, Duffy, and Fishman (1992) suggest that "authentic" implies more than a physical representation, level of fidelity, or a realistic setting. They argue that authenticity requires a focus on metacognitive processes and a holistic view of the task. If the learner is to function effectively in real-world environments, he or she must develop the metacognitive skills (i.e., the ability to direct and monitor one's own learning and performance) required to function in complex, dynamic environments. The training environment must support the learner in assuming responsibility for establishing and monitoring learning goals and strategies. If training does not support the development of metacognitive skills, the learner is less likely to consider alternative rules or strategies, how the strategy should be used in particular situations, or when the rules should be adapted given certain contingencies.

LEARNING TRANSFER

Resnick (1989) refers to learning transfer as the holy grail of educators - everyone seems to be in search of it. Unfortunately, the difficulty of effective transfer of learning is well documented in the literature (Detterman, 1993). Transfer has been defined as the capacity to see something as relevant in a new context that was learned in a different context, apply what has been learned in one context to a new context, and apply old knowledge in a new context that is sufficiently novel to require learning of new knowledge (Perkins & Salomon, 1988). Transfer involves using knowledge in many different ways. It is this challenge that the constructivists feel their approach to learning addresses. The constructivist view of transfer relates to the construction of knowledge that the learner can apply flexibly. Learning experiences which help the learner to develop knowledge that can be applied to a wide range of situations depend on events that are situated (Brown et al., 1989a), where the situation or context has particular meaning for the learner. Constructivists believe that instructional activities that are situated in real-world context and provide the opportunity for the learner to build an internal representation of knowledge have a far greater chance of transferring from the learning environment to real world situations (Duffy & Jonassen, 1992).

From the constructivist perspective, Prenzel and Mandl (1993) have identified two desired goals of transfer. First, the learner must learn how to handle problems in specific contexts. Second, the learner must overcome narrow contextuality. These researchers note that in principle it should be possible to study the effects of constructivist learning approaches on transfer since a distinction can be made between the situation or phase in which knowledge and skills are constructed and the situation or phase in which knowledge is subsequently applied. However, according to Prenzel and Mandl, the constructivists argue that "construction" occurs in both the learning and application situations. The construction processes in turn affect learning processes within both situations. Because of this process, Prenzel and Mandl believe that sorting out the effects of constructivist approaches on transfer will be difficult. Messner (1978) has developed one interesting perspective on transfer from a constructivist perspective. He terms learning as the construction of a (cognitive) structure; whereas transfer is defined as the reconstruction of a structure. It is important to note that the topic of transfer has yet to be subjected to any type of rigorous study from a constructivist perspective (Tobias, 1991).

Low Road and High Road Transfer

Perhaps more applicable to training decision tasks is the work of Salomon and Perkins (1989) on sorting out the how and why of learning transfer. They argue that transfer occurs in a number of different ways, and distinguish between low road and high road transfer. Low road transfer involves the spontaneous, automatic transfer of highly practiced skills, with little need for reflective thinking. Thus, low road transfer reflects the effects of extended practice, and the distance of transfer (i.e., the extent that knowledge transfers to a novel environment) depends on the amount of practice and the variability of contexts.

Salomon and Perkins suggest that low road transfer can lead to the situation where skills and knowledge are contexually welded and less able to transfer when the situation changes. They believe that the mechanism that results in this contextual welding is based upon a cognitive element being learned and practiced until it becomes automatic. On a later occasion in another context, the stimulus characteristics may sufficiently resemble those of the earlier context to trigger the element automatically. Salomon and Perkins note that automaticity may increase processing efficiency, but reduce response flexibility. Thus, an automatic response in one context may have disastrous effects in a similar yet different context.

If, as the constructivists suggest, static drill and practice may reduce the ability to transfer skills and knowledge to new situations, alternative training strategies may be needed to better prepare individuals for working in decision intensive environments such as the CIC and the aircraft cockpit, where training cannot feasibly prepare or rehearse individuals and teams to deal with every critical situation that may arise.

One real world example illustrates the danger of low road transfer. The nuclear reactor accident that occurred in 1979 at Three Mile Island is one pertinent and dramatic example (see Perrow, 1984). While the sequence of events that led to the accident are exceedingly complex, there are several characteristics of this disaster that are noteworthy with respect to transfer of training. First, there was a series of multiple failures that were somewhat ambiguous to the operators because they were not in a direct operational sequence, thus possibly contradicting much of the information received during training. Second, because of the change in sequencing, many of the events taking place were incomprehensible to the participants. The cues being evaluated were not of the kind the operators had been trained for on the simulators that were used during training. At one point, two key indicators that should, and always had moved together were providing totally different readings. One operator noted that he knew they were experiencing something different, but each time they made a decision, it was based on something they knew about or experienced before. While there was logic to the actions, Perrow suggests that the mindset established was based on an expected universe (i.e., one similar to the situations that had been encountered in training) and not on what was actually occurring.

Constructivists might suggest that the skills and knowledge of the operators were contextually welded (via low road transfer) to those situations they were trained for or previously had experienced. Therefore, the operators' ability to adapt their thinking or transfer their knowledge to a new context may have been limited, in part because of the nature of their training.

High road transfer involves the explicit, conscious formulation of abstractions in one situation that allows making a connection to another. Salomon and Perkins suggest that the principal ingredient in high road transfer is mindful abstraction. This is defined as the deliberate abstraction of a principle, idea, strategy, or procedure from one context, which then becomes a bridge for transfer to another context. (Note the constructivists' emphasis here on not only what trainees know, but on how trainees actively monitor their own cognitive processes, infer and relate new information to old, and organize and review knowledge--in other words, the development of metacognitive skills.) Mayer and Greeno (1972) claim that active learning where individuals achieve abstractions by themselves facilitates further transfer than passive reception.

Salomon and Perkins note a number of issues that require investigation in examining instructional design strategies that may foster high road transfer:

- What conditions of learning promote mindfulness and in particular promote the building of abstractions?
- What conditions of learning encourage reflecting back on potentially applicable elements from prior learning?
- What learning habits does the learner bring to the situation that would assist in high road transfer?

Transfer and Inert Knowledge

A number of researchers (Bransford, Vye Kinzer & Risko, 1990; Cognition and Technology Group, 1990, 1991a) refer to the transfer issue as a problem of "inert" knowledge. That is, knowledge that the learner has in memory, but does not know how to apply effectively to new environments and a broader range of applications. This process is illustrated by the transfer research of Gick and Holyoak (1980). During the learning phase of one of their experiments, subjects were introduced to the problem of a fortress which should be taken by means of distributing forces directed toward a focal point. After subjects demonstrated knowledge of this concept, they were confronted with a radiation problem requiring the application of the same strategy used for the fortress. Many subjects were able to find the solution and make the necessary transfer of learning - but only when given the hint that the fortress problem might be related to the radiation problem. Thus, the knowledge gained during the learning phase remained inert until sufficiently stimulated.

Prenzel and Mandl (1993) suggest that abstract knowledge (as contrasted with abstracted knowledge) conveyed within a certain learning context will limit the range of application of that knowledge at first. They define this as inert knowledge. However, if knowledge is abstracted (mindful abstraction) through many and varying applications, multiple applications will be discovered by the learner. This knowledge can then be flexibly applied. Knowledge with only a few elements in the application range is rigid. Again, this raises the question of how to support the training developer to develop and modify training scenarios for this purpose.

The constructivists suggest a number of instructional strategies to flexibly apply knowledge. These approaches include:

- Situating learning in order to relate knowledge to action, to create a significant and problem oriented context, to initiate active engagements, and to support understanding
- Emphasizing application contexts in order to define both potential and non-potential application contexts
- Examining the subject matter from multiple points of view in order to develop more flexible knowledge and knowledge access
- Decontextualizing in order to include different examples, to bridge domains, and to foster abstraction

High Transfer Training (HITT)

Finley et al. (1993) have identified a methodology for training soldiers to perform maintenance on different items of equipment or different configurations of equipment. Their approach is to present training in a manner that will allow effective transfer of training across a group of related equipment. Several objectives characterize high transfer training (HITT) implementation strategies: (a) Certain similarities can be identified that exist between equipment or other objects that are encountered in the individual's area of technical specialty; (b) The trainee can be taught to identify and respond to these similarities; and (c) The learner has, and can make use of, resources available in order to figure out how to proceed. Overall, the desired result is that the learner is able to operate and repair equipment that may differ from the equipment on which they were trained. Finley et al. found that soldiers trained using the HITT strategies performed more effectively. Anecdotal data suggest that this training approach results in soldiers with more confidence and eagerness toward working on equipment for which they have not been specifically trained.

Even though the learner was not trained on a specific piece of equipment, he or she may still be able to operate and repair it;

While these researchers have specified a design approach that contains many ingredients of a traditional instructional design methodology, a number of the implementation strategies for HITT can be easily modified to reflect a constructivist learning approach.

These include:

- Providing a learning environment where the learner can determine similarities as well as differences between the equipment or systems that they work with, and the nature of these differences. Helping the learner understand that this knowledge *will* transfer to the operational (authentic) environment.
- Providing sufficient and varied practice encourages the integration of similarities into the learner's representation of knowledge and the building of a more abstract framework.
- Allowing collaborative interaction within and between groups of learners including opportunities to articulate questions and answers about related objects or systems. This may foster confidence, understanding of variety, and the building of mindful abstraction, reported by Salomon and Perkins (1989) as critical for high road transfer.
- Increasing learner responsibility in the learning process by reducing the amount of feedback to students while training additional types or variations of equipment.
- Providing learning situations that force the learner to actively use all resources available to them. This will foster confidence in the learner that he or she can deal with situations or equipment not specifically trained.

PERFORMANCE ASSESSMENT

Jonassen (1992) singles out evaluation as the most difficult issue related to constructivism and argues that if constructivism is to be a valid methodology for delivering instruction, it should also provide a valid set of criteria for evaluating the outcomes of that instruction. However, at the present time, as Tobias (1992) has pointed out, there is a great deal of esoteric jargon on the issue but little empirical substantiation.

Objectivism and constructivism differ significantly on the role of performance assessment. In objectivist instructional design approaches, the goals and objectives are set by instructional designers. Normative or criterion-referenced objectives are used to define the desired learning outcomes. Instruction is built around the learner exhibiting these pre-established set of behaviors. Constructivists suggest that criterion-referenced instruction and evaluation are prototypic objectivist constructs and not appropriate evaluation methodologies for constructivist environments. They argue that instead of attempting to map the structure of an external reality onto the learner, instruction should assist the learner in constructing meaningful and accurate conceptual representations of the external world. Assessing what learning has taken place in constructivist oriented learning environments requires alternative approaches to evaluation. Jonassen states that evaluation from a constructivist perspective should be less of a reinforcement and/or behavior control tool and more of a self-analysis and metacognitive tool.

Bednar et al. (1992) view evaluation from the constructivist perspective as requiring an examination of the learner's thinking process. One approach is to require the learner to address a problem in their subject area and defend their decisions. A second approach is to require the learner to document the process through which they have constructed their view of the content area or of a specific issue. Bednar et al. identify two key elements in this approach to evaluation:

(1) Is the perspective that the learner develops in the content area effective in working in that area? For example, can the learner arrive at reasoned solutions to problems in the field?

(2) Can that the learner defend his or her judgments?

Constructivists representing an extreme approach to evaluation suggest that assessment must be goal free; that is, they believe that if specific goals are known before the learning process begins, the learning process as well as the evaluation would be biased. The belief is that the goals of the learning drive the instruction, which in turn controls the student's learning activities. Jonassen, in taking a more moderate view, recognizes that if constructivism is to become an accepted instructional approach, accepted and tested methodologies for performance evaluation must be devised. Jonassen has identified a number of characteristics that should be a part of these methodologies. Several of these that are noted below may be relevant to training decision intensive tasks.

- Evaluation should focus on learning outcomes that will reflect the intellectual process of knowledge construction.
- Outcomes of constructivist environments should assess higher order thinking skills; e.g., the "find" level of Merrill's (1983) taxonomy, "cognitive strategy" level of Gagne's (1987), and the "synthesis" level of Bloom's (1984) taxonomy.
- Assessment needs to determine how well the learner solves relevant problems.
- Evaluation should include the opportunity for the learner to defend a particular position.
- Effective assessment should be integrated into the instruction. Evaluation guidelines should be available during the learning process so both student and instructor can determine how well the learner is progressing.
- Several opportunities should be provided for the learner to demonstrate the ability to transfer learned skills to unique situations.
- Since constructivist strategies prescribe instruction that is anchored in meaningful, real-world context, evaluation should also take place in contexts that are as complex as those used during instruction.

- Learning should not be determined by a single behavior set. It should be referenced by a domain of possible outcomes, each of which should be able to provide acceptable evidence of learning.
- Whenever feasible, constructivist evaluation should include evaluation from a panel of reviewers, each with a meaningful perspective from which to evaluate the outcomes. This might include evaluators with different degrees of experience.
- If products are being evaluated, a portfolio of products, rather than a single product of learning should be evaluated.

Assessment within constructivist environments will pose significant challenges for organizations with established objectivist design traditions. For example, constructivists suggest that careful consideration should be given to identifying an appropriate range of evaluation criteria and avoiding a single set of evaluation criteria. Setting up such an approach to assessment for Navy training communities will require a significant re-design of training curriculum with considerable importance placed on selectivity in utilization of constructivist strategies. The following presents some possible ways assessment might be woven into constructivist learning environments.

1. Constructivist Strategy: Cognitive Apprenticeship

Approach to Assessment: Assessment for learning environments using cognitive apprenticeship as a learning approach should include providing continuous feedback to the learner regarding performance. This is necessary as the learner strives to model the thought processes of the expert/instructor in solving a problem or performing a task. The instructor should function as a facilitator and encourage self-assessment by requiring the learner to document areas of knowledge, show evidence of increased understanding of complex concepts and describe the apprentice - expert modeling process that has occurred. The instructor must objectively document observations concerning progress and concepts that have learned. Assessment should also include solving problems unique to the content area or discipline and demonstrating knowledge transfer to unique situations that may be encountered by the learner.

2. Constructivist Strategy: Collaborative Learning

Approach to Assessment: Assessment when multiple perspectives and collaborative learning are utilized requires that the learner demonstrate an awareness of additional perspectives on a problem or concept. This can be done by the learner identifying similarities and differences as well as strengths and weaknesses between alternative perspectives of a particular issue or concept. The instructor may require that the learner attempt to solve a relevant problem by designing and taking an approach suggested by another individual. Instructor personnel should utilize a range of acceptable criteria including acceptable answers generated by other instructors, experts or students. The learner should be evaluated using observation on their participation in collaborative problem solving authentic to the discipline or field. On-going feedback should be provided on how well the learner can verbally assess the merits of alternative approaches or concepts related to solving the problem. Assessment must include provisions for immediate feedback and additional instruction and practice, if required. Since collaborative learning may include team training of some nature, assessment approaches are needed that recognize the complexity of, for example, group problem solving. These approaches must be able to provide feedback on what the group is doing well and not well. Instructor(s) observation using specially designed checklists with a range of acceptable behaviors may provide one approach.

3. Constructivist Strategy: Situated Cognition and Authentic Activities

Approach to Assessment: Situated learning requires evaluation that is situated as well. That is, if learning is conducted in authentic environments, evaluation should also be conducted in similar situations. As with other constructivist approaches, a range of acceptable performance criteria should be generated, particularly if a goal of learning in authentic environments is to foster learning transfer to multiple events or situations that cannot possibly be anticipated during training. Opportunities for the learner to demonstrate flexibility in thinking within the authentic environment must be developed. Asking the learner to describe his/her thought processes and mapping this thinking to a set of general "guideposts" may be one method to assess skill development.

4. Constructivist Strategy: Structured Problem Solving

Approach to Assessment: Assessment for this instructional approach should center on the learner demonstrating various approaches to solving authentic problems. Since one of the goals of this constructivist learning approach is to reduce learner errors and a sense of confusion, assessment and feedback should strive to prevent incorrect performance even during assessment. This is accomplished by integrating instruction with assessment. Instruction should be broken into small learning segments with assessment immediately following each segment. Assessment design should include a set of possible solutions that is readily available for the instructor and learner to review and gauge skill development.

5. Constructivist Strategy: Problem- Oriented Learning

Approach to Assessment: Assessment for problem-oriented learning requires that the learner demonstrate skill development in a number of areas related to the process of problem solving that are authentic to the domain being studied. A great deal of the emphasis in this learning approach is on how well the learner handles preparatory information. Assessment should strive to determine how well the learner accomplishes these preparatory activities. First, the learner should be required to present several hypotheses concerning the nature of the problem. The problems presented should be real-world reflecting the culture of the subject domain. A range of acceptable responses should be generated during the design of the assessment. Next, the learner should explain where they believe the gaps exist in their knowledge of the problem. Again, a range of acceptable responses should be available for the instructor to use. Third, the learner should be assessed on how well he/she evaluates available facts, as well as how effectively they collect missing data from documentation and/or subject experts. General guidelines for assessing these steps should be developed by instructional designers. Complementing this assessment should be a more objectivist approach to assessment where the subject knowledge of the learner is queried through more traditional assessment techniques.

6. Constructivist Strategy: Simulation

Approach to Assessment: Simulation represents a potentially powerful constructivist learning tool. One of the underlying goals of assessment using simulation as learning strategy should be to determine how well the learner has identified and conceptually organized the various interrelationships and dependencies that are integral to a simulation. There are several ways to address assessment, depending upon the particular simulation strategy being used. Several of these forms of simulation and possible assessment techniques follow.

Active Interactive Simulation. The authentic environment provided by various levels of active interactive simulation such as a full motion simulator offers significant opportunity for knowledge construction in complex decision making environments. Assessment should strive to evaluate the learner's ability to apply knowledge to a wide range of situations. For example, in training flight emergency procedures, assessment should require the student following the session to verbalize thought processing for several of the emergencies encountered. Evaluation might consider how symptoms of the emergency were processed, i.e., what options or range of options were considered, possible systems involved, conflicting data encountered, as well as ambiguous data encountered. A range of acceptable answers should be available to the instructor. Feedback should accompany assessment similar to that used for cognitive apprenticeship - the goal being to help the student pilot model the thought processing/problem solving strategy of an experienced pilot.

Database Access Discovery Learning Simulation. A potential assessment approach for this type of simulation might include using a gaming type strategy where the learner acquires points or receives a score. During assessment, the learner is given a problem to solve related to the field of instruction. Information to solve the problem exists in some form in a database that can be queried. The greater the amount of pertinent data is extracted from the database, the larger the score of the learner. The assessment assumption is that the more points that are scored, the greater the number of interrelationships and patterns the learner has conceptualized. Such an approach to assessment should be used with caution. It is very possible the learner has acquired the knowledge of certain game strategies that will result in more points, but at issue is whether he/she fully understands the relationships that exist.

High Transfer Training (HITT). HITT focuses on maintenance skill transfer for a family of related equipment. Assessment should require the learner to demonstrate skill mastery on progressively more diverse equipment. Initially, the learner should demonstrate skills on one piece of equipment. As the training progresses, the learner should be given repair tasks that force the learner to apply skills to different pieces of equipment. In addition to performance tests, the instructor should query the learner on similarities and differences that exist, as well as what resources should be used for troubleshooting or to solve other maintenance related problems. As with other constructivist approaches to assessment, a range of acceptable answers should be developed and available for the instructor.

APPLICATION OF CONSTRUCTIVIST APPROACHES TO NAVY TRAINING REQUIREMENTS

The Navy operational environment is increasingly defined by the forces of rapid change and increasing task complexity. In response, alternative instructional approaches may be necessary to prepare Navy personnel to deal with changing job requirements. Constructivism, as described in the preceding chapters, provides the instructional design community with one potentially useful alternative. However, a number of questions must be addressed in attempting to apply the constructivist approach to specific training settings: Under what conditions is constructivism an appropriate design approach? What characteristics of the learning environment, subject area, or learner suggest the use of this learning approach? What Navy training environments would be potential candidates for a constructivist learning environment? This chapter explores these issues and provides some discussion on selective, or in some cases a "tempered" use of constructivism to address Navy training challenges.

WEAVING CONSTRUCTIVISM INTO THE TRAINING PATH - SELECTING AN APPROACH TO DESIGN

In chapter 1, we compared behaviorism, cognitivism and constructivism as three alternative approaches to instructional design. Are there conditions under which one approach is more effective than another? Shuell (1990) notes that the nature of the learning process changes as learning progresses. For example, what might be the most effective for a novice learner encountering an ill-structured or complex concept for the first time, may not be more effective for someone who is more knowledgeable regarding the subject matter. Similarly, the teaching of basic procedural information typically will not be accomplished in the same manner as concepts or problem solving. Furthermore, the depth and breadth of instruction may vary based on the level of the learners.

Ertmer and Newby (1993) describe two dimensions that may help evaluate the application of different training design approaches to specific training settings. The first dimension is the learner's level of task knowledge. As an individual acquires more experience with a given content, he or she progresses along a low-to-high knowledge continuum. This range can be described in the following manner:

1. Recognizing and applying rules, facts and operations
2. Thinking like a professional to extrapolate from general rules to particular cases
3. Developing and testing new forms of understanding and actions when familiar categories and ways of thinking fail and adaptive approaches are necessary

Behavioristic design approaches appear to address training requirements dealing with information content, facts, and recall. Cognitive design approaches appear to have value for teaching problem solving where defined facts and rules are present or known. Constructivists suggest that the design approaches they advocate can address ill-defined problems where the learner must adapt and function well when optimal conditions do not exist.

A second dimension reflects the level of cognitive processing required by the task. At the low end of this continuum are tasks requiring a low degree of processing such as basic paired association, discriminations and rote memorization. Behavioristic approaches appear to be effective in addressing these types of training requirements. Training tasks requiring an increased degree of processing such as classification, rule or procedural execution are associated more frequently with design approaches that are more cognitively oriented. At the high end of the continuum are tasks demanding greater levels of cognitive processing such as analytic, diagnostic or investigatory problem solving. Cognitive approaches may be more appropriate for these types of tasks.

It should be noted that some instructional strategies, while predominately behaviorist, cognitivist or constructivist, contain elements of more than one approach to design. Thus, while Ertmer and Newby imply a theoretical distinction between these three design approaches, such a separation may not exist in actual practice. In other words, some instructional strategies may contain a blending of two or even three design approaches.

In summary, borrowing on quotes from P.B. Drucker, cited in Ertmer and Newby (1993): "We need behaviorist triad of practice/reinforcement/feedback to enlarge learning and memory. We need purpose, decision, values, understanding -- the cognitive categories -- lest learning be mere behavioral activities rather than action." To this Ertmer and Newby add: "... we also need adaptive learners who are able to function well when optimal conditions do not exist, when situations are unpredictable and tasks demand change, when the problems are messy and ill-formed and the solutions depend on inventiveness, improvisation, discussion, and social negotiation.

SELECTING NAVY TRAINING ENVIRONMENTS THAT ARE CANDIDATES FOR CONSTRUCTIVIST LEARNING

While it is interesting to speculate on Navy training environments that may be candidates for constructivist learning approaches, the value of constructivism as a design approach and appropriate applications have yet to be empirically substantiated by other than a few narrative studies. In addition, these few studies have looked at more educational rather than training applications. Models for making decisions on which design approaches to take, such as the one proposed by Ertmer and Newby, are beneficial for preliminary discussions but must be subjected to more rigorous scrutiny. However, based upon arguments put forth by the constructivists, it is possible to identify characteristics of Navy work environments that might be candidates for constructivist learning. These can be broken into characteristics of the job and training environment.

Job Task Characteristics

- *Are job requirements and environments decision intensive*? Is effective decision making a principal ingredient for job success?
- *Does an ill-structured work environment exist?* Does job performance involve applying knowledge to cases where multiple conceptual structures are encountered, each of which is individually complex?
- *Is job performance dependent upon the ability of a team to coordinate action, integrate information and resources?* Is group decision support or a shared mental model integral to successful team performance?
- *Does the need exist for high levels of conceptual thinking*? Does job performance require levels of thinking such as divergent, evaluative and synthesis?
- *I s the "reconstruction" of knowledge necessary to adequately respond to situational demands?* Does job performance require drawing upon previous related experiences to build a new approach to solving a problem or meeting a situational demand?
- *Is there difficulty in providing training for a number of novel or complex operational situations*? Can training only feasibly address a sampling of possible job requirements?
- *Does the need for problem solving skills exist, and are incomplete data a characteristic of the job environment*? Will the job performer have to solve problems where a lack of complete information may be frequently encountered?
- *Do misconceptions or misinterpretations frequently occur*? Does a danger exist for misinterpretation of data?
- *Are authentic experiences critical for training?* Does effective job preparation require experiences that will enable the learner to adopt and internalize the "culture" of the discipline?
- *Must the job performer make sense out of multiple and/or complex interrelationships*? Will the job performer encounter a "system" that requires he/she to interpret a series of interdependencies prior to acting?
- *Is conceptual understanding more important than procedural skills*? Is conceptual understanding an important fundamental basis for effective job performance?

- *Is conceptual understanding required to perform a wide variety of procedural skills*? Will the job performer continually be challenged to apply conceptual knowledge to a variety of procedures?
- *Is there risk in drill and practice being contextually welded to specific situations*? Does a danger exist that the practice regimen will result in the learner not being able to recognize changes to the problem or situation that could require an alternate strategy to be applied for successful resolution?
- *Must the job performer recognize subtle clues, indicators, or symptoms that can easily be confused*? Will the job performer encounter a variety of subtle indicators such as system status that require enhanced and flexible diagnostic skills?
- *Is "high road" transfer of training critical to prepare the job performer for unique situations?* Will the building of mindful abstractions within the learner be essential in order to foster effective learning transfer to unique or rarely encountered situations?
- *Must the job performer be adaptive to new situations?* Will effective adaptation to constantly changing or new situations be a characteristic of the job environment?
- *Does problem solving or decision making involve recognizing complex relationships*? Will the learner have to interpret and make sense out of a number of complex interdependencies in order to make a decision on a course of action?
- *Does problem solving or decision making require a rapid analysis or diagnosis*? Will the job performer need to quickly conceptualize the nature of the problem or situation and available alternatives?
- *Is decision making required in unpredictable situations*? Is there a likelihood that the job performer will encounter unpredictable situations requiring decision making by an individual or a team?
- *Are job requirements constantly evolving such as in an emerging weapon system or new equipment*? Will the job performer be faced with, and have to adapt to a constantly evolving set of job requirements resulting from forces such as technology change?

Training Environment Characteristics

While training requirements should dictate the characteristics of the training provided, certain realities of a training environment or community must be taken into consideration in determining if a constructivist approach could be a candidate for a particular Navy training application. These considerations include the following:

- *Extent to which opportunities exist or can be made to exist for the learner to help regulate his or her training.* Constructivist approaches emphasize the importance of the learner regulating learning to an extent, contributing to one's own feedback and judgment, and keeping concentration and motivation high.
- *Behavioral task analysis does not provide the kind of information needed to support instructional development that enhances high road transfer.* Training communities mandating traditional task analysis may overlook critical cognitive training requirements, thus, not recognizing the need for alternative design strategies that could enhance high road transfer.
- *Extent to which learning responsibilities fall heavily on the learner.* The greater the learning responsibilities that may fall on the shoulders of learner, the more that constructivist approaches should be considered. For example, emerging shipboard training environments associated with DIS, may require a greater amount of learner self-regulation to construct meaningful training experiences, interpret feedback, and "reconstruct" additional learning experiences. Constructivist approaches may be particularly effective in this type of environment.
- *Extent to which instructional personnel are open to teaching practices that may differ from those they have been taught.* Many constructivist learning strategies require the instructor(s) to interact with the learner in different ways, e.g., facilitating rather than directing. Instructional personnel will need to be open to learning new teaching techniques.
- *Extent to which alternative methods of assessment are given consideration and review.* Assessment for constructivist strategies may requires alternative approaches that will need to be carefully conceived, tested and modified. Multiple iterations of this process may be necessary until success is achieved.
- *Extent to which multiple sets of assessment criteria are possible.* Constructivists suggest that multiple sets of assessment criteria are necessary since the manner in which knowledge is represented in each individual is unique. There may be training settings in which establishing multiple sets of assessment criteria is just not possible.
- *Extent to which alternative instructional design strategies such as cognitive apprenticeship and collaborative learning will be considered as viable options.* Whether or not a particular training community will even consider the viability of alternative instructional approaches will be a key factor in implementing and testing constructivist design approaches.

A TEMPERED CONSTRUCTIVISM FOR NAVY TRAINING

Some proponents of constructivism (e.g., Cunningham, 1991) offer views on the nature of learning that might be considered extreme. A number of the assumptions put forth by these theorists could significantly limit the utilization of constructivism as a potential instructional design alternative for addressing selective Navy training requirements. Merrill (1991) notes that the assumptions that are made by extremists about the learning process are unnecessarily restrictive, would be labor intensive to implement, and may actually prevent the more effective instruction that they seek. Advocates of constructivist approaches that are more moderate (e.g., Winn, Duffy, Jonassen) describe a "tempered" constructivism that appears to offer instructional designers flexibility that could be more palatable to various Navy training communities.

Merrill has identified some of the extreme constructivist views that could potentially limit the application of this design approach. One such view is is that content cannot be prespecified because every learning task is unique. That is, prespecified learning objectives contradict the concept of knowledge construction by an individual. Such a stance would be extremely limiting in that it implies that prepackaged instructional materials are not consistent with the nature of learning. A more tempered use of constructivism would incorporate prespecified knowledge and desired outcomes to an extent in order that a learning structure could be established for institutional as well as unit training. To be implemented in a practical way in almost any Navy environment, knowledge must be represented in some knowledge base, even for training strategies such as free play simulation, hypertext, or virtual reality. Without such a tempered approach, the burden placed upon the learner would be unreasonable, and instructors would have little structure from which to guide or monitor training because of the lack of specified objectives and prepackaged training materials. In support of this argument, Perkins (1991b) recognizes at least three issues that may cause serious difficulty: (a) the high cognitive load of constructivist learning, (b) the heavy responsibility placed on learners, and (c) the initial awkwardness of buying in to a different learning process. Without a more tempered approach, it cannot be envisioned how the constructivist approach to learning would be of interest to the Navy training community.

A second version of extreme constructivism insists that knowledge construction requires authentic experiences exclusively. Merrill argues that to insist on context never being separated from use is to deny the teaching of abstractions. The work of Salomon and Perkins (1989) has suggested the importance of abstraction in learning transfer. In Navy training requirements, a great deal of concepts associated with introductory learning typically require content being separated from use. Although authentic experiences should be a goal whenever possible, practicality again dictates a more tempered approach.

A CONSTRUCTIVIST EXAMPLE - TRAINING EMERGENCY PROCEDURES FOR THE SH-60 HELICOPTER

The following is an example of how a constructivist approach could be woven into the training curriculum for training emergency procedures for the SH-60 helicopter.

Introduction

The advent of high fidelity full-motion simulators has enabled the aviation training community to practice a wide variety of emergency procedures in nearly authentic environments. The flight dynamics that can be modeled for aircraft emergencies provide the trainee with a close approximation of what would be encountered during an actual flight emergency. Typically, pilots are systematically drilled in the procedures for dealing with emergencies. NATOP procedures are clearly defined for most critical emergencies. Emergencies with the potential for catastrophic results have procedures that incorporate critical memory items. That is, step by step procedures are required to be memorized by pilots during initial training and are practiced frequently as part of skills sustainment training. The initial drill and practice to learn the procedures for dealing with aircraft emergencies are often trained in a static cockpit procedures trainer. Aviation communities lacking a cockpit procedures trainer or simulator may role-play emergency procedures. Some of this role-play may take place in the actual aircraft during training flights.

In training emergency procedures, a number of issues surface that may benefit from the use of constructivism as an approach to training design. Two of these are: (1) the danger of traditional drill and practice leading to contextual welding and the potential this creates for ineffective decision making during emergencies, and (2) the significant role that crew coordination plays in effectively dealing with flight emergencies. The following paragraphs suggest how selective constructivist design strategies could be integrated into training emergency procedures to deal with these two important issues.

System Theory

System theory provides the conceptual background for pilots to understand the workings of a particular aircraft system (e.g., hydraulics, electrical, engine). The goal is to provide the pilot with sufficient knowledge of the aircraft systems and their interaction so that correct diagnosis of malfunctions will be facilitated during an emergency. It is generally recognized that training cannot feasibly expose the student pilot to every problem for every aircraft system that may occur. Teaching system knowledge will enhance skills in diagnostics and better prepare the learner to deal with unforseen emergencies. System knowledge is typically a precursor to procedural training for emergencies. A tempered constructivist approach may enhance how system theory is approached.

Design Strategies:

1. Structured Problem Solving. Initially, the student pilot is presented with a series of symptoms for malfunctions. Rather than being told the source of the problem, the learner must construct both the cause and probable outcome assuming that no action or an incorrect action is taken. A hypertext database is available for study to diagnose the problem. This database contains a listing of symptoms and hypertext links to different system diagrams. Clicking on various parts of the system diagrams brings up narrative descriptions and additional information on potential system problems. Initially, the instructor is available to clarify terms, guide the learner if asked, but not to provide conclusions. The instructor will help the student get back on track if he or she steers too far away from information that will help solve the problem. The goal is for the student to build a sufficient level of abstract thinking related to system functioning, emergencies and symptoms. At this point in the training, the instructor wants to ensure that students are not forming absolutes; i.e., developing a mind set that symptom set A always results in malfunction A or symptom set B always results in malfunction B. It is important that the student pilot learn to conceptualize the emergency in terms of symptoms, both subtle and distinct, and in terms of system functioning. The pilot needs to be continually thinking: What is happening to the system? For example, why was the flow of hydraulic fluid interrupted? What are the possible causes? What should I be hearing or seeing? What are the implications for continued flight? Allowing the learner to search a database for possible answers will facilitate construction of critical concepts and abstractions that will aid in learning transfer if the student encounters a different set of symptoms. Having the instructor available to keep the learner on track will reduce the risk of inaccurate concept formation, as well as eliminate possible frustration.

2. Multiple Perspectives/Collaborative Learning. Knowledge construction is extended by integrating multiple perspectives and collaborative learning strategies. Malfunctions, which may include multiple malfunctions at one time, are presented to a team of students. Each student is asked to verbalize a hypothesis and support this hypothesis with system information. The student team is encouraged to sketch out system diagrams or communicate in any manner that will build a case for identifying the systemic causes for the malfunction. Problems developed for this activity include those that have obvious or subtle causes, as well as single and multiple causes. Training progresses from evaluating a single system to multiple systems. The instructor is responsible for facilitating the collaborative environment and building a cooperative effort. As with structured problem solving, learning goes beyond simply memorizing how a system works but entails being able to form an internal representation of the system and its relationship to possible malfunctions and emergency situations.

Evaluation of a student's understanding of system theory is conducted in several ways. Traditional evaluation, such as objective tests, are used to assess basic knowledge. Advanced concept formation is assessed through panel discussions that require narrative responses from each student. Problems similar in scope but unique in content are presented. Instructors may then assess each student's performance.

Diagnostic Troubleshooting and Corrective Action

Once the instructor staff determines a sufficient level of system theory has been attained, diagnostic troubleshooting and corrective action is addressed. This phase of the instruction focuses on corrective procedures once a malfunction has been correctly diagnosed.

Design Strategies:

1. Simulation Using Multimedia. Students are assigned lessons for each system that has been covered during the theory phase of instruction. A series of simulated malfunctions are presented through a set of symptoms that are presented visually and, as appropriate, aurally. For example, students hear a simulated crew discussion describing cockpit indicators, or the actual sounds of malfunctioning equipment (such as a compressor stall), and description from crew members of how the aircraft is handling. From this information, students diagnose malfunctions and perform simulated procedures by determining and selecting the appropriate actions from a list presented on the screen. Multiple and varied emergencies are presented during the lessons. Remediation is not simply the display of the correct answer to the learner. For example, if an incorrect diagnosis is made, the student is allowed access to a database with system information to "reconstruct" the correct relationship between the symptom and the system. When the learner feels he or she has obtained the conceptual knowledge needed, he or she can return to the simulation and attempt a new diagnosis and corrective action.

2. Drill and Practice with the Cockpit Procedures Trainer. Many inflight emergencies require almost instantaneous action and decision making by the crew. At times, a conditioned response or performance of memorized procedures is an absolute necessity. Preparation for these situations requires extensive practice. Whereas drill and practice is clearly a behaviorist design approach, it is necessary for developing the rapid stimulus-response needed for effective performance. By integrating constructivist design approaches with behaviorist and cognitivist approaches, we ensure a training program that includes rapid response by the crew when the source of a malfunction can be clearly identified. We also reduce the danger of contextual welding, where the possibility exists for the wrong corrective action being applied because a learned response was tied too closely to stimuli that resembled that normally associated with a particular malfunction.

Aircrew Coordination Training

Aircrew Coordination Training (ACT) has become an increasingly integral part of flight training. A great deal of its value is in dealing with unforseen emergency procedures and in optimizing the chances that when an emergency occurs, the crew will respond effectively as a team. A number of design strategies with a constructivist orientation could be used for ACT as it relates to training for emergency procedures.

Design Strategies:

1. Scenario Driven Free-Play Simulation with Computer Generated Feedback. Using this strategy, the learner is able to construct an internal representation of the linkage between crew coordination skills and the effective handling of emergency procedures or, more importantly, in structuring the cockpit environment to prevent pilot induced errors leading to emergencies. Initially, each student pilot is presented with a simulated mission to fly that is hosted on a desktop computer. The student can query the system for prebrief information including additional information about the mission such as weather expected and aircraft maintenance history. In addition, the student can investigate the composition of the crew including experience, background, and other pertinent information that could effect how well the crew will perform during the mission. As the mission progresses, the student is presented with various decisions concerning the handling of crew coordination issues. At certain points, the learner is also presented with emergency events. The outcome of each emergency is dependent not only on how quickly the correct diagnosis is made, but how well the student has controlled the various dimensions of crew coordination (e.g., communication, leadership, situational awareness, assertiveness) leading up to the emergency. During the scenario, the learner can query the system for feedback on various metrics such as crew communication, level of assertiveness, or the degree of situational awareness present. The goal is for the learner to build an understanding of the numerous relationships and interdependencies that exist in any mission that effect the outcome. This conceptual understanding is fostered by the constructivist approach of allowing the user to manipulate the scenario elements, determining their effect by studying the associated metrics, and then adjusting their "game" strategy until the metrics are optimized.

2. Multiple Perspectives and Collaborative Learning. A variety of design approaches with a tempered constructivist orientation can be used to enhance crew coordination skills. Collaboration as a design strategy could be used to develop, compare, and understand multiple perspectives on crew resource issues. For example, a group of learners are given sketchy details of a documented mishap. Each member of the group is encouraged to build a different hypothesis for the mishap that includes the how and why of crew coordination breakdowns. The instructor facilitates the discussion, encouraging related "war stories" to add to the collective wisdom of the group.

Operational Flight Trainer (OFT)

The final phase of the emergency procedures training incorporates the use of an Operational Flight Trainer. At this point in the instruction, system knowledge and the procedures for aircraft emergencies are integrated in a highly authentic practice environment using the OFT. Several levels of this training are possible. A tempered constructivism can be woven into each of these levels.

Design Strategies:

1. Structured Problem Solving. Initially, the SH-60 cockpit crew is given a series of loosely structured missions to fly with limited emergency procedures to perform. The background of the pilot and the airframe he or she has transferred from (i.e., fixed or another rotary wing) will determine how much time must be allocated to basic stick skills and contact maneuvers before exposure to flight emergencies in the OFT. The instructor's role at this point is to present emergency procedures at varied points in the mission, e.g., takeoff, cruise, special maneuvers, approach. When necessary, and there appears to be the risk of an incorrect diagnosis, the instructor freezes the scenario and intervenes to prevent errors and a sense of confusion. The instructor provides a set of possible solutions. The crew is then guided through the process of evaluating these options. This level of instructor support is eliminated as soon as possible.

2. Guided Generation. This strategy is an extension of structured problem solving. At this point, aircraft malfunctions that are more difficult to diagnose or which contain subtle symptoms are introduced. Multiple malfunctions occurring over short periods of time are also presented as well as emergencies that require more than diagnosis and corrective action. For example, the crew needs to evaluate the impact of the emergency on continuing the mission and determining alternate landing sites. One of the roles for the instructor in this design strategy is to facilitate problem finding as well as problem solving. While the instructor may provide guidance, this is done in such a manner that he or she appears to be another member of the crew; that is, asking questions, communicating concerns, attempting to clarify issues, or offering options that should be considered.

2. Cognitive Apprenticeship. For this strategy, the crew is presented with a series of mission focused scenarios. These scenarios contain emergency situations that are complex, varied, unique, and often require the crew to make sense out of incomplete or ambiguous data. Cognitive apprenticeship as a constructivist strategy can be implemented during the OFT mission scenario but more likely is used after the hop is completed. Once a flight is over, decision making segments of the flight are dissected by the instructor. This is not done as a critique would be handled with a snapshot of what was done well or poorly. Rather, the instructor uses the videotape of the mission and presents the problem solving strategies that he/she would use to deal with each emergency or decision point. As soon as practicable, the crew flies a new mission with emergencies containing similar elements as the previous flight. The student crew has the opportunity to model the problems solving strategies of an experienced pilot and more importantly to begin to internalize the problem solving strategies used and the effective use of available resources.

RESEARCH RECOMMENDATIONS

Several emerging trends in the fields of behavioral science and training have converged to make this a very timely occasion to evaluate the application of constructivist approaches to decision making training. First, the constructivist approach to training emphasizes the use of active, dynamic simulations to train complex skills. The use of active simulations is a very current and active area in military training (see Baker, Prince, Shrestha, & Oser, 1993; Simons, 1993).

Second, recent technological advances in simulation and training technologies, such as the use of multimedia and virtual reality technology, offer innovative approaches for developing dynamic simulations. For example, virtual reality systems enhance the sense of immersion in the virtual environment. The constructivist perspective would imply that enhanced context in training would lead to greater training effectiveness. Although some studies have shown positive results of training in virtual environments (Knerr et al., 1994), others have found no evidence of positive transfer of virtual reality training to a real-world task (Kozak, Hancock, Arthur, & Chrysler, 1993). Therefore, current technologies may offer enhanced immersion and context previously unobtainable, yet the question of whether, or under what conditions, enhanced context leads to more effective training has not been adequately addressed.

Third, there is an emerging concern among training professionals that the traditional drill and practice regimen that characterizes many training programs may yield knowledge and skills that are contextually welded to particular situations and less easily transferred to novel environments. The requirement to adapt to changing task conditions is a defining characteristic of most decision intensive military tasks. The constructivist approach is one attempt to evaluate alternative instructional approaches for achieving effective transfer of complex skills.

In the following, we identify several critical research needs or requirements. These topics include research to examine the application of constructivist approaches to Naval training and to address gaps in the knowledge base that currently limit our understanding of constructivist principles. A number of research topics are identified throughout this report. Those that appear below are those considered to be the highest priority efforts. We examine research needs in three broad areas: (a) the evaluation of constructivist training approaches, (b) the development of tools to support training development, and (c) the role of context and immersion in training and simulation.

CONSTRUCTIVIST TRAINING APPROACHES

The preceding chapters have described a number of constructivist training methods and principles that provide an innovative, yet largely untested, approach to training and simulation. We have noted a number of general questions that must be addressed in attempting to apply the constructivist approach to specific training settings. Under what conditions is constructivism an appropriate design approach? What characteristics of the training environment, subject area, or learner suggest the use of this approach? What specific Navy training environments are potential candidates for application of constructivist learning principles? Answers to these general questions will be found by conducting primary level experimental research. Specific research topics include the following.

A Phased Approach to Constructivist Training. The constructivist emphasis on retaining the complexity of the task environment in training presents a dilemma in that the novice learner may be overwhelmed by this information. Some have suggested a phased approach to training, in which novice learners are presented the basic concepts and principles to be acquired, and then more advanced training focuses on gaining an understanding of the interrelationships among task elements in a more complex "real-world" environment (see Spiro, Feltovich, Jacobson, & Coulson, 1992; Winn, 1991). The goals of instruction at this more advanced stage are that trainees gain an understanding of the conceptual complexity inherent in the task environment and are able to transfer their acquired knowledge to novel situations. Thus, Spiro et al. argue that the certain instructional practices may work well for introductory learning (such as focusing on general principles), whereas constructivist approaches may be more appropriate for application during advanced knowledge acquisition. Whether this approach can overcome the problems of training a complex task in a complex manner has not been empirically established.

Trainee Immersion and Training Effectiveness. The constructivist approach emphasizes the importance of realistic context in training, suggesting that the more the trainee is involved or immersed in the training context, the more effective the training. This position is implicit in current virtual reality training efforts, in which the goal is to immerse the trainee in the simulated environment. Although the importance of providing exposure to real-world context in training is acknowledged by the training community, little research has examined the extent to which immersion impacts learning. For example, do increasing levels of immersion enhance or detract from training? Experimental research should be conducted to examine the role of immersion in training and simulation.

Collaborative (Team) Training. The constructivists note that in the real world, people learn and work in collaborative settings, yet most learning in training settings takes place individually (Resnick, 1988). The constructivists argue that much of what we know is learned through social interaction and collaboration, and therefore training should provide access to this distributed knowledge. More specifically, they argue that establishing a collaborative instructional environment provides a means for developing multiple perspectives, a key component of constructivist instructional strategy. Further research is needed to examine the role of socially constructed knowledge in teams (i.e., How can team training enhance the development of multiple perspectives? Can this type of knowledge enhance the performance of dispersed teams?).

Enhancing Mechanisms for On-the-job or Embedded Training. The constructivists speak of knowledge as "situated." That is, knowledge is a part of the real world activity, context, or environment in which it is developed and used. Knowledge that is isolated from the real world context in which it is situated becomes *inert* knowledge, information that we know, but do not know how to use. Therefore, embedded or on-the-job training should play a particularly strong role in the constructivist perspective. Attention should be directed to the examination of training technologies and approaches implied by the constructivist position that will improve the mechanism for embedded or on-the-job training.

The Role of Self-Direction in Training and Simulation. The constructivist literature suggests that the more complex the skill to be trained and the more ill-structured the learning domain, the greater the need for learner involvement in determining the direction of instruction. Constructivists place a strong emphasis on self-direction in formulating individual representations of knowledge. Advocates of this position embrace technology based approaches to learning such as hypertext and databases where the individual is free to browse and construct meaningful relationships. One approach that may be worthy of further research and which builds on a number of constructivist premises is the concept of Strategic Design (SD). In SD, the instructional designer identifies milestones that he or she would like the learner to pass and experience. As the learner encounters these events in an interactive environment such as virtual reality or distributed simulation, the learner is confronted with problems to solve, or ambiguities that will require further exploration. Through the sum of these experiences as well as repetition, the learner is able to build internal representations of knowledge which the constructivists suggest are more apt to transfer to unique situations. When used in conjunction with strategies such as cognitive apprenticeship and collaborative learning, SD may provide an effective alternative to the current behaviorally-based approaches to design. The advantages of studying such approaches become more evident as significant emphasis in Navy training is placed on transferring training requirements to the operational environments. Reduced shore-based training will demand instructional approaches that shift the burden from the instructor to the learner.

Training individual skills, such as meta-cognition or situational awareness. The constructivist approach argues that the training of complex skills must be situated in the real-world context; thus training simulations must attempt to maintain the complexity of the real world setting. Procedures such as the use of "cognitive apprenticeship" to model expert performance may provide effective ways to develop trainee knowledge in these complex task settings. However, the application of these instructional approaches to train individual skills such as situational awareness or metacognitive skills has not been clearly established.

DEVELOPMENT OF TOOLS TO SUPPORT THE TRAINING DEVELOPER

As noted in previous chapters, the constructivist approach offers a number of potentially valuable applications to Naval training. However, we have also noted a number of potential drawbacks of this approach, not the least of which is that it is somewhat more complex than traditional instructional design and places considerable demands on the training developer.

The constructivist approach emphasizes learning as a constructive process in which the trainee builds (or constructs) an internal representation of knowledge that is based on experience. This experience is gained through active problem solving in real-world contexts. A critical aspect of performance in the real-world is the ability to respond to changing situational constraints -- to be able to construct new plans, strategies, and behaviors in response to novel or complex task environments. Constructivist learning theory postulates that instruction should be presented in meaningful contexts and with multiple practice opportunities that will aid the learner in making sense of novel or complex task environments. With sufficient representation established, the learner can make use of acquired knowledge in a variety of contexts.

Constructivist instructional approaches stress the importance of presenting or revisiting the same material (or training activity) at different times in rearranged contexts, for different purposes, and from different conceptual perspectives. This concept of "multiple representations" is particularly important in that the complexity of many military operational environments require the trainee to make sense of complex, novel, or ambiguous stimuli that may not have been addressed directly in training. If knowledge is abstracted (mindful abstraction) through many and varying representations, multiple applications will be discovered by the learner. This knowledge can then be flexibly applied to novel contexts.

However, the problem of how to provide multiple representations in training presents a considerable difficulty for the training developer. This will demand much more creativity from training developers, and will require guidance to be provided on how to develop and modify training scenarios for this purpose, along what dimensions should scenarios be modified for multiple presentation, and how to assess trainee performance. The development of tools to assist the scenario developer in this task is a critical area that requires further research.

THE ROLE OF CONTEXT AND IMMERSION IN TRAINING AND SIMULATION

The constructivist approach emphasizes context in training, or the importance of immersing the learner in a realistic training environment. This concept, which has been variously referred to in the educational community as context, in simulation and training as fidelity, and in the virtual reality community as immersion or presence, is mentioned prominently in the training research literature. Currently, a number of advanced research efforts are developing virtual environments for training. Virtual reality technology attempts to narrow the separation between the user and the computer-generated world. Thus, one primary feature of virtual environments is the sense of immersion or presence in the simulated environment. That is, the user gains the sense of being immersed in the actual context of the setting. Marshall, Purvis, Wolff, and McCormack (1992) note that a successful training system "creates a sensory-immersing environment...an experience of actually being there." However, although hardware designers are busily developing advanced visual, aural, and tactile systems to enhance immersion, there are some critical questions regarding the extent to which enhanced context contributes to training effectiveness.

Several research studies have examined the question of immersion in training and simulation. Witmer and Singer (1994) describe four categories of factors that are likely to impact the degree of immersion or presence experienced by trainees: (a) control factors, or the extent to which actions taken by the trainee to control or manipulate the training environment are immediate and natural; (b) sensory factors, referring to the quality, richness, and variety of information presented to the senses; (c) distraction factors, or the extent to which the trainee is isolated from the external physical environment; and (c) realism factors, including field of view, scene detail, texture, and realism. However, the extent to which these factors determine training effectiveness is unclear. Whereas Lintern et al. (1989) found no effect of scene detail on training, Lintern et al. (1987) found positive effects.

Other research has examined the extent to which training is enhanced when the trainee is an interactant in the training process (i.e., immersed in the training) versus an external observer. Yuille et al. (1994) examined trainees who were either active participants in a training drill or observers. Results indicated that participants in the drill tended to recall more information than did observers, but there was no difference in the accuracy of information recalled.

However, there is one valuable and existing source of data that may be brought to bear on this issue. Jacobs, Prince, Hays, and Salas (1990; see also Hays, Jacobs, Prince, and Salas, 1992) conducted a noteworthy research effort to integrate the available evidence on the effectiveness of flight simulator training. This meta-analysis identified a number of characteristics associated with the effectiveness of simulator training. By re-analyzing the data on training effectiveness, we were able to cast light on some of the critical issues raised by the constructivist approach. For example, does greater trainee "immersion" lead to greater training effectiveness? During Phase I, we conducted a preliminary re-analysis of the Hays et al. database to provide an initial examination of this question.

One important component of presence or immersion in the context of flight simulators is the nature of the visual information presented to the learner, and one elemental aspect of this visual information is the field of view (FOV) afforded to the learner by the simulator. By way of illustration, consider the differences in FOV in two different simulators: The FOV afforded the learner in the 2F87F flight simulator (50° horizontal FOV, 38° vertical FOV, for a multiplicative composite of (50° X 38° = 1900) is considerably less than that afforded the learner in the ASPT flight simulator (300° horizontal FOV, 150° vertical FOV, for a multiplicative composite of (300° X 150° = 45000).

Intuition may suggest that greater presence or immersion would be provided by the simulator that gives the widest FOV. Fortunately, we can examine this possibility by charting out the effectiveness of simulator training as a function of the FOV afforded the learner by the simulator. Specifically, for the 11 hypothesis tests available to date for simulator vs. jet aircraft-only training (the 10 hypothesis tests integrated in Jacobs et al., 1990, plus one derived for Reid and Cyrus, 1974, Study 1), simulator training effectiveness was moderated by FOV. However, contrary to expectations, simulator training effectiveness was inversely related to FOV, $r = -.497$, $Z = 2.409$, $p = .00800$. That is, the greater the FOV afforded the learner, the worse the effectiveness of flight simulator vs. jet aircraft-only training.

This suggests an intriguing theoretical elaboration which requires more extensive examination in this meta-analytic database. We may need to develop a distinction between maximum enrichment and matched immersion. Maximum enrichment refers to the sheer quantity of information presented to the learner by the simulator. Alternatively, matched immersion refers to the optimum match between the information presented in the flight simulator and the information actually presented in the aircraft. The foregoing inverse relation between FOV and flight simulator effectiveness could be a reflection of either one of these factors.

For example, it is entirely possible that (contrary to initial expectations), the greater FOV impairs flight simulator training effectiveness because the visual display of the simulator exceeds the maximum enrichment needed for effective learning. This is reminiscent of traditional human factors considerations of information overload, and suggests that simulator effectiveness could be improved by reducing the enrichment of the visual display. Alternatively, it is entirely possible that the greater FOV impairs flight simulator training effectiveness because the visual display of the simulator exceeds the visual display of the actual aircraft. This suggests that simulator effectiveness could be improved by trying to better match the enrichment of the simulator's visual display to that of the actual aircraft. In other words, the question becomes why is performance after training on the wide FOV ASPT flight simulator worse than that after training on the narrow FOV 2F87F flight simulator? Is it that students in the ASPT flight simulator suffer more information overload (maximum enrichment), or is it that 2F87F flight simulator provides a better match to its aircraft than does the ASPT flight simulator?

Moreover, the impact of trainee immersion on training effectiveness is likely to be dependent on factors such as the type of task, experience level of the trainee, or the phase of training. For example, there are likely to be conditions (perhaps during initial skill acquisition) under which greater immersion in training may detract from learning. It is possible that immersion may enhance training for more experienced trainees, but not for novices. There is currently little research that has addressed these issues.

A further research topic that arises from this research literature is the impact of context on team training. What does context mean in a team training environment? How do you enhance "team cohesion" in virtual space? If presence involves being subjectively drawn into a training scenario, does this detract from the broader team awareness required for coordinated team performance?

These questions and possibilities can be examined by conducting a meta-analytic research study to update and extend the results of Hays et al. (1992). In conducting this analysis, several methodological concerns that limit the utility of the initial research can be addressed. First, there were no actual meta-analytic tests of the significance of the various moderators/predictors considered in the report. Without meta-analytic focused comparisons, we are not able to formulate any conclusions about the apparent effects of specific moderators on the effectiveness of simulator training. Second, there were a number of studies within the extant literature between 1957-1986 that were excluded from this previous effort. For example, in Appendix A, Jacobs et al. (1990) listed 17 reports as being excluded due to "insufficient statistics." However, a preliminary re-evaluation of the data in these reports indicates that at least 7 of these reports provide sufficient statistics to extract an includable test of the hypothesis, even though the actual test of the hypothesis was not presented in the report.

For example, Reid and Cyrus (1974, Study 1) reported the mean flight performance for three groups of students: those who received simulator training (the experimental group) (50.68), those who first received only an aircraft orientation ride (44.02), and those who received only the standard Undergraduate Pilot Training (UPT) syllabus (the control group) (54.06). The F-test reported for the analysis of these data, $F(2,66) = 7.42$, is (as indicated in Jacobs et al.'s (1990) Appendix A) not an appropriate statistical test of the hypothesis that simulator training transfers to actual performance in the aircraft. That is, this F-test on df=2 simply tests the omnibus hypothesis that there is some difference amongst these three groups. However, what is needed is the more focused test of the significance of the difference between the experimental (simulator) group and the control (UPT syllabus) group.

It should be noted that Reid and Cyrus (1974, Study 1) did report the results of Tukey's Honestly Significant Difference (HSD) test comparing all three mean performances. However, the extreme conservativeness of this a posteriori test is of questionable utility insofar as the comparison between the experimental and control groups in this study is by definition an apriori comparison (indeed, it was the whole point of conducting the study in the first place). Moreover, Tukey's HSD test may provide a conservative answer to the simpler question of whether or not the difference between each pair of means is significant; however, this "yes/no," "significant/not significant" answer does not render a precise estimate of the effect size representing this difference.

Fortunately, as detailed in Mullen (1989), anytime the authors of a paper report the omnibus F-test and the means for all of the relevant conditions, we can work backwards to determine the MSerror term, which can be used to calculate the a priori t-test comparing the relevant means (which, in turn, can be used to render an estimate of effect size). Actually, Reid and Cyrus (1974, Study 1) reported the entire ANOVA table, including this needed MSerror term, which makes this particular reconstruction a bit less tedious. Thus, the test of the difference between the performance of the experimental (simulator) group and the control (UPT syllabus) group is $t(66) = -1.276$, which renders an effect size of $r = -.155$. The negative direction of this effect here represents the fact that the experimental (simulator) group performed worse than the control (UPT syllabus) group. Similar procedures will allow the extraction of includable hypothesis tests from Reid and Cyrus (1974, Study 2), as well as from several other studies (e.g., Thorpe et al., 1978; Woodruff et al., 1976) identified in the Jacobs et al. (1990) database, but not included in their analysis.

Furthermore, the literature search in the initial meta-analysis was restricted to experiments published between 1957-1986. While this thirty-year time-span is impressive, the fact remains that this database is now ten years out of date. Studies conducted in the ten years since (indeed, in response to) Jacobs et al.'s (1990) effort are necessarily excluded from this previous effort.

In summary, the constructivist principle of enhanced context in training is certainly not a new concept. However, the most recent version of this principle, embraced by the virtual reality community, is that increased trainee immersion will lead to more effective training. Accordingly, system designers are rushing headstrong to develop advanced visual, aural, and tactile systems to enhance trainee immersion. However, as the very preliminary results we have presented suggest, enhanced immersion may not necessarily lead to more effective training. It is likely that this relationship depends on a number of factors, such as the phase of training or the type of task to be trained. At present, we do not have the answers to these questions.

There are a number of important research questions that can be addressed by conducting an updated meta-analysis of the training effectiveness research. What training factors increase training immersion? What factors decrease immersion? Does increased immersion enhance training? Does the type of task or phase of training moderate the relation between immersion and training effectiveness? The meta-analytic strategy proposed is an empirical strategy which has had a high success rate in similar domains (see Driskell, Willis, & Copper, 1992; Driskell, Copper, & Moran, 1994; Mullen & Copper, 1994; Mullen, Anthony, Salas, & Driskell, 1994).

CONCLUSIONS

Constructivist learning theories represent a new approach to instructional design, and at face value, the constructivist perspective appears to offer an innovative and potentially valuable approach to enhance the effectiveness of Naval training. The task environment that is a primary focus of constructivist learning approaches--tasks that are complex, dynamic, ill-structured, knowledge-intensive, and ambiguous--is representative of a wide range of Naval applications. The central concepts implied by the constructivist approach--immersion, cognitive flexibility, active learning, the construction of mental models--are issues that are currently prominent in the military training community. Finally, specific constructivist instructional strategies may lead to innovative and effective approaches to military training, transfer, and performance assessment.

The constructivist approach offers a novel perspective on old problems, and has generated considerable activity and interest in the educational and instructional community. However, ideas that seem bright during academic discourse often fade in the harsh reality of empirical test. Caution must be exercised in uncritically adopting the latest trends, especially when the training implications of the constructivist approach are compelling yet essentially untested.

The primary obstacle to realizing the potential value of constructivist applications to Naval training is the fact that very little empirical research has been conducted in a training environment. A number of principles and innovative approaches that derive from the constructivist approach have been identified in this report; however, whether these approaches can benefit Naval training must still be determined. The next step that is required is to conduct a systematic program of empirical research to operationalize these approaches in a military training setting and test their effectiveness in enhancing Naval training.

We have identified three priority areas in which research should be pursued:

- The first research task is to test the application of specific training principles and strategies derived from the constructivist approach in a Naval training setting. This will require (a) selecting a Naval training application of interest, such as training sonar operators, (b) developing specific training interventions, such as the use of multiple representations in constructing flexible knowledge, and (c) evaluating the impact of these interventions on training outcomes.

- The constructivist principle of providing multiple representations in training to enhance flexibility of knowledge use may be particularly important in military training in that the complexity of many military operational environments require the trainee to make sense of complex, novel, or ambiguous stimuli that may not have been addressed directly in training. However, this approach will demand much more creativity from training developers, and research is needed to develop tools to assist the scenario developer in this task.

- The constructivist emphasis on context in training, or the importance of immersing the learner in a realistic training environment, is not a novel concept in the training literature. The most recent application of this principle, adopted by those in the virtual environment community, is that increased trainee immersion or "presence" will lead to enhanced training. Yet, the question of whether, or under what conditions, immersion leads to more effective training has not been adequately addressed. Given recent advances in simulation and in virtual environment technology that enable greater realism to be obtained in training, further research is needed to examine the impact of trainee immersion on training effectiveness.

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