Creating Expertise: A Framework to Guide Simulation-Based Training

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ABSTRACT

The US Armed forces, and increasingly its coalition allies, continue to embrace simulation technologies as a solution to many training challenges. As these applications broaden in scope, it will no longer prove effective to use high-end systems to train all tasks. Rather, it will become critical to match training requirements to specific training technologies. Simulation tools such as Tactical Decision-Making Simulations (TDSs) seem to offer substantial benefits as modalities for training complex cognitive skills including planning and decision making, while keeping development and procurement costs significantly lower than those associated with high-end systems. However, the training community lacks a means of ensuring that utilization of these technologies for cognitive training will enhance battlefield performance. To aid TDS developers in designing tools that support the acquisition of expertise, a framework was generated to describe the evolution from beginner to expert in ill-structured environments. The framework reflects the notion that effective training enables learners to move toward a state of expertise, where good decisions are made quickly and automatically despite environmental ambiguity and chaos. Thus, the framework describes 1) five levels of proficiency and characteristics of learners at each stage; 2) the *process* by which individuals transition from one stage to the next; and 3) indicators of proficiency that enable diagnosis of a learner's current stage. Two main assertions anchor the framework. First, in cognitively complex domains such as tactical thinking, learning consists of developing and refining mental models which enable individuals to accurately size up situations and apply action scripts to accomplish the objectives. Second, mental model development relies differentially on a range of training environments and techniques depending on the learner's current proficiency level. Since the framework has implications for training in ill-structured environments regardless of specific domain content, it should prove adaptable across services and even across alliances.

ABOUT THE AUTHORS

Dr. Karol G. Ross is a Senior Research Associate at Klein Associates. Her areas of expertise are the training and assessment of tactical thinking skills and qualitative research methods. She conducts research and development for the US Army, the USMC, and the Office of Naval Research. She has recently directed and participated in research to produce an online tool to support subject-matter experts in developing training vignettes and cognitive task analysis for the design of anti-terrorism training. Currently, she is directing and conducting research to develop a new assessment method for tactical thinking skills, online training scenarios for coalition warfare, and knowledge management processes and vignettes for the US Army's Battle Command Knowledge System. She has developed and conducted workshops on qualitative research methods for the military and industry. Formerly, as a Research Psychologist for the US Army Research Laboratory, she conducted research and development for training adaptive tactical thinking for digitized Brigade operations at the US Army Command and General Staff College. She also previously served as a Senior Researcher for BDM International studying Division-level battle staff performance and as a Research Psychologist for the Army Research Institute in Germany working in the area of large-scale simulation training for echelons above Corps. In addition, Dr. Ross has eight years of experience working in the healthcare industry and ten years of experience as an adjunct faculty member at the graduate level in education, training, and organizational development. She regularly publishes and presents in the areas of naturalistic research and training. She earned her doctoral degree from the University of Tennessee in Experimental Psychology in 1984.

Jennifer K. Phillips is a Research Associate II at Klein Associates. Her research interests include skill acquisition and the nature of expertise, and she has applied her research to the development of decision-centered training interventions. Ms. Phillips served as project lead on an Army-sponsored effort to develop decision skills training for small unit leaders in military operations in urban terrain and worked on a similar effort to provide Web-based decision skills training to Air Force personnel for Operations Other Than War. Ms. Phillips has worked on several USMC-sponsored efforts to re-engineer existing command posts and design experimental combat operations centers. She led an Army-sponsored program of research to identify the process by which individuals make sense of situations as they unfold and to develop training designed to bolster sensemaking skills. Most recently she has been involved in a USMC program of research to improve the use of Tactical Decision-Making Simulations for training decision making and sensemaking skills. She is experienced in using Cognitive Task Analysis methodologies to capture components of expertise in a range of domains, and has used Cognitive Task Analysis to identify training requirements for purposes of knowledge management. Ms. Phillips received a B.A. in Psychology from Kenyon College in 1995.

Dr. Gary Klein is Chief Scientist of Klein Associates Inc., a company he founded in 1978 to better understand how to improve decision making in individuals and teams. The company has more than 35 employees working on projects for government (e.g., Army, Navy, Air Force, Marines) and commercial clients (e.g., Mead Johnson, Kodak, McKinsey, and Procter & Gamble). Dr. Klein is one of the founders of the field of Naturalistic Decision Making. His work on recognitional decision making has been influential for the design of new systems and interfaces, and for the development of decision training programs. He has extended his work on decision making to describe problem detection, option generation, sensemaking, planning and replanning. In order to perform research on decision making in field settings, Dr. Klein and his colleagues have developed new methods of Cognitive Task Analysis. Klein Associates has used Cognitive Task Analysis methods to study decision making in more than 60 domains, including firefighting, command and control, software troubleshooting, healthcare, and consumer purchasing. Dr. Klein has presented workshops on Cognitive Task Analysis and on Decision Skills Training to a wide variety of professionals in the US and abroad. Dr. Klein received his Ph.D. in Experimental Psychology from the University of Pittsburgh in 1969. He was an Assistant Professor of Psychology at Oakland University (1970-1974) and worked as a Research Psychologist for the US Air Force (1974-1978). He has written more than 70 papers and co-edited three books. He is the author of *Sources of Power: How People Make Decisions* (1998, MIT Press), which has sold more than 16,000 copies and has been translated into four languages, and *The Power of Intuition* (2004, A Currency Book/Doubleday).

LCDR Joseph Cohn, PhD. is a designated a Naval Aerospace Experimental Psychologist. Currently, LCDR Cohn is Senior Scientist and Policy Research Fellow at the Naval Research Laboratory's Warfighter Human Systems Integration Lab, where he is developing a comprehensive theoretical framework for establishing the cost/benefit tradeoffs associated with using Virtual Environments for Training.

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INTRODUCTION

Simulation-based training has the potential to offer substantial benefits. It can be low-cost and support multiple practice iterations in a short period of time compared to full-scale simulations or field exercises. It's often engaging and motivating (Druckman, 1995; Garris, Ahlers, & Driskell, 2002; Prensky, 2001), as well as easy to distribute. However, the training effectiveness for complex cognitive learning is unclear, and guidelines for design and effective use at advanced levels of training are lacking, making other potential benefits irrelevant.

To address these issues, we developed a framework for effective design, use, and assessment of simulation-based training for complex cognitive skills. The framework is driven by research describing how individuals learn in domains marked by uncertainty, ambiguity, and dynamically changing conditions. It suggests instructional techniques for activating and supporting the learning process and learning assessment strategies within a wide range of simulation-based training solutions in complex cognitive domains. We have applied the framework to the design and use of Tactical Decision-Making Simulations (TDSs) for training tactical thinking skills.

Tactical Decision-Making Simulations are PC-based simulation trainers that leverage the technology found in commercial video games. In some cases, TDSs have been adapted from existing commercial off-the-shelf games. In other cases TDSs are developed solely for military training purposes. Tactical Decision-Making Simulations typically enable solitary and team versus computer, or force on force play. While the TDS acronym was coined by the US Marine Corps, other military branches have utilized similar PC-based training simulations.

Our efforts focused on TDSs for training tactical thinking for two primary reasons. First, there is a great deal of face validity for TDSs, and their potential is widely accepted. Their game-like quality and immersive environment resembling that of actual tasks, without the expense and safety concerns of field exercises, make them popular training tools. Learners are enthusiastic to use TDSs, and they report high levels of motivation to improve their TDS performance (Baxter, Ross, Phillips, Shafer, & Fowlkes, 2004). Furthermore, the technologies offer the ability to capture every move, keystroke, and communication made by the learner, providing high potential for assessment and after-action review. Second, there is a critical need for a guiding framework that would support TDS design and implementation for training tactical thinking skills. Many desktop simulations are still developed with a greater focus on the affordances of technology than on what the system should do to provide value as one of several pieces of a broader training program. Of the research that has been conducted to determine what constitutes a good simulation or game, the focus has largely been on attributes that promote learning by successfully engaging or motivating the user, rather than contextual characteristics that result in learning (Garris et al., 2002). Despite the lack of sound guidance, system developers are beginning to articulate learning objectives at the front end of the development cycle in an effort to improve the learning value of the technologies. However, the community still lacks an underlying training concept and prescription for harnessing technological advances to support the desired learning.

In this paper we present an abridged version of the general cognitive skill acquisition framework, including 1) a stage model of cognitive proficiency that describes characteristics of novices, experts, and proficiency levels between the two extremes; 2) a theory regarding the nature of complex cognitive skill acquisition; 3) principles derived from the theory of skill acquisition and their implications for simulation-based training; and 4) general training guidance for each developmental stage. It should be noted that while the unabridged training framework (found in Ross, Phillips, Klein, & Cohn, 2005) provides guidance regarding learning assessment, we will not tackle that issue in this paper. We will, however, present one component of the cognitive skill acquisition framework for the tactical thinking domain to illustrate the adaptation of the general framework for a particular domain. Both the general and tactical thinking frameworks are documented in their entirety in Ross et al. (2005).

LEVELS OF PROFICIENCY

The purpose of training is to move individuals from their current state of skill and knowledge to a higher state. What, then, are the stages of learning, and what do individuals know and do at each stage? Without a commonly recognized account of the stages along the learning continuum, we lack a roadmap with which to pinpoint where we are with a particular individual and where we're trying to go. A great deal of research documents the nature of expertise and contrasts it to novice behavior—the two ends of the performance continuum (e.g., Chi, Glaser, & Farr, 1988; Ericsson & Smith, 1991; Feltovich, Ford, & Hoffman, 1997). A much smaller body of research illuminates the nature of performance between these two endpoints. This research has generated and tested a stage model of proficiency that delineates knowledge and abilities at stages between novice and expert (Benner, 1984, 2004; Dreyfus & Dreyfus, 1986; Houldsworth, O'Brien, Butler, & Edwards, 1997). These two bodies of literature provide the basis for our description of the five stages of cognitive proficiency in complex, ill-structured domains.

"An ill-structured knowledge domain is one in which the following two properties hold: (a) Each case or example of knowledge application typically involves the simultaneous interactive involvement of multiple, wide-application conceptual structures (multiple schemas, perspectives, organizational principles, and so on), each of which is individually complex (i.e., the domain involves concept- and case-complexity); and (b) the pattern of conceptual incidence and interaction varies substantially across cases nominally of the same type (i.e., the domain involves across-case irregularity)" (Spiro, Feltovich, Jacobson, & Coulson, 1992, p. 60). In other words, each individual case is complex, and there is considerable variability across cases. Professionals must exercise a great deal of judgment to flexibly apply their knowledge. These domains can also require that decisions be made under conditions of time pressure and high stakes. Tactical thinking is one such domain, as are many types of medical practice, firefighting, and law enforcement work.

In the military tactical thinking domain, the types of challenges that require a great deal of judgment include applying the commander's intent to plan and execute operations, predicting the adversary's course of action, leveraging key pieces of terrain, and orchestrating the timing of events in a mission. Cognitive expertise in these skills is domain-specific, and performance is based on recognitional processes (Klein, 1989). Such context-driven skills develop only with practice and experience doing the tasks in context; they cannot be developed by reading a text or listening to classroom instruction (Spiro & Jehng, 1990). Tactical Decision-Making Simulations are well-suited to providing training for such complex cognitive functions because they enable mission practice and feedback in a simulated environment that approximates the real world.

The Five-Stage Model of Skill Acquisition

To understand proficiency in complex cognitive domains, we have extended the original stage model of performance developed by Dreyfus and Dreyfus (1986). The five-stage model describes performance at levels during the transition from novice to expert. The model has been applied to training and instruction within domains such as combat aviation, nursing, industrial accounting, and chess (Benner, 1984, 2004; Dreyfus & Dreyfus, 1986; Houldsworth et al., 1997). Like tactical thinking, these domains demand that decisions be made quickly in environments that are complex, ambiguous, and dynamic. Findings from the literature on expertise and naturalistic decision making have been incorporated to enhance the existing five-stage model and guide our framework for training complex cognitive skills. The five stages are summarized below and represented in Table 1.

Stage 1: Novice
Individuals who perform at the Novice level have limited or no experience in situations characteristic of their domain. They may have a great deal of textbook or classroom knowledge of the domain, but what places a person in Stage 1 is the shortage of actual lived experience. Because the Novice's understanding of the domain is based largely on context-free rules, the resulting performance is quite limited and inflexible.

Stage 2: Advanced Beginner
Advanced Beginners have acquired enough domain experience that their performance is marginally

Table 1. Snapshot of the Stage Model of Cognitive Skill Acquisition (Adapted from www.devmts.demon.co.uk/dreyfus.doc)

<table>
<tr><th>Stage</th><th>Characteristics</th><th>How knowledge is treated</th><th>Recog-nition of relevance</th><th>How context is assessed</th><th>Decision making</th></tr>
<tr><td>Novice</td><td>Rigid adherence to taught rules or plans
Little situational perception
No discretionary judgment</td><td>Without reference to context</td><td rowspan="2">None</td><td rowspan="3">Analytically</td><td rowspan="4">Rational</td></tr>
<tr><td>Advanced Beginner</td><td>Guidelines for action based on attributes or aspects
Situational perception is still limited
All attributes and aspects are treated separately and given equal importance</td><td rowspan="4">In context</td></tr>
<tr><td>Competent</td><td>Sees action at least partially in terms of longer-term goals
Conscious, deliberate planning
Standardized and routinized procedures
Plan guides performance as situation evolves</td><td rowspan="3">Present</td></tr>
<tr><td>Proficient</td><td>Sees situation holistically rather than in terms of aspects
Sees what is most important in a situation
Perceives deviations from the normal pattern
Uses maxims, whose meanings vary according to the situation, for guidance
Situational factors guide performance as situation evolves</td><td rowspan="2">Holistically</td></tr>
<tr><td>Expert</td><td>No longer relies on rules, guidelines, or maxims
Intuitive grasp of situations based on deep tacit understanding
Intuitive recognition of appropriate decision or action
Analytic approaches used only in novel situations or when problems occur</td><td>Intuitive</td></tr>
</table>

acceptable. They can recognize, either on their own or when pointed out to them, recurring meaningful "aspects" of the situation. Aspects are global characteristics that are identifiable only through prior experience; the prior experience serves as a comparison case for the current situation. Advanced Beginners can begin to develop their own "guidelines," or rules of thumb, that stem from an understanding of the domain attributes and aspects, but they have not built the interconnectedness between concepts or developed the ability for flexible application (Dreyfus & Dreyfus, 1986).

Stage 3: Competent

The Competent stage is marked by an analytical, hierarchical approach to formulating, prioritizing, and managing longer-term goals or objectives. This perspective gives the operator a better sense of the relative importance of various aspects of the situation. The transition from Advanced Beginner to Competent is highlighted by a shift from highly reactive behaviors, where actions are taken right when a problem surfaces, to more planful behaviors, where the learner can see the larger picture and assess what actions must be taken immediately and what can wait. However, Competent performers tend to rely on the plan to drive their behavior more than any situational elements that may arise. They hesitate to change their plan mid-course despite the introduction of new or updated information.

Stage 4: Proficient

Learners at the Proficient level have moved away from perceiving situations in terms of independent attributes and see the situation as an inseparable whole where the attributes are interrelated and woven together. The situation is not deliberately analyzed for its meaning; an assessment occurs automatically and dynamically because the learner has an extensive experience base from which to draw comparisons. However, decisions regarding appropriate actions continue to require some degree of detached analysis and deliberation. While Competent performers generally cannot change their plans when faced with conflicting information, Proficient individuals fluidly adjust their plans, expectations, and judgments as features of the situation change.

Stage 5: Expert

The fifth and final stage is Expertise. At this level the individual no longer relies on analytic rules or guidelines. Performance is intuitive and automatic. The Expert immediately understands which aspects of the situation are critical and does not waste time on the less significant aspects. He or she knows implicitly what action to take, and can remedy a situation quickly and efficiently. Other markers of expert knowledge and performance can be found in Table 2. (For a full review of the knowledge and performance characteristics of Stages 1-4, see Ross et al., 2005.)

DEVELOPING COMPLEX COGNITIVE SKILLS

How do individuals progress from novice levels of performance through the more advanced stages? We view this process as the learner's development and use of mental models. While several definitions exist for the term "mental model," we prefer the following: "A mental model is a representation of some domain or situation that supports understanding, reasoning, and prediction" (Gentner, 2002, p. 9683). We would add that mental models also support action.

Cognitive Transformation Theory

Learning and improving complex cognitive functions in the real world must happen in context. There are no general, abstract skills to teach that lead to expert decision making, situation awareness, and problem detection in a professional domain. The quality of decision making or meaningfulness of situational understanding depends heavily on accumulating and structuring knowledge and learning to use those structures in context. Mental models are the structures that facilitate expertise. We therefore concentrate on mental models as the mechanism to best understand and facilitate the advanced learning process, with the understanding that domain-specific experiences are the method.

Klein and Baxter (in preparation) have formulated a theory of Cognitive Transformation to explain how experts structure experiences and feedback into mental models. The theory treats learning as a form of sensemaking (e.g., Weick, 1995) and states that people do not develop cognitive skills in the same way they develop motor skills, through practice and feedback and a gradual improvement over time and repetitions. The central claim of Cognitive Transformation is that people serially replace and improve their mental models as they abandon previous beliefs and move on to new ones. However, at each juncture the existing mental models direct what they attend to, and they resist disconfirmation, making it difficult for them to diagnose what is lacking in their beliefs and to take advantage of feedback.

According to Cognitive Transformation, the path to expert mental models is not direct and incremental, but discontinuous. Cognitive Transformation asserts that people sometimes develop misconceptions or "bugs" within their mental models that inhibit future learning. During experiences, people use their existing mental models to diagnose situations, derive actions, and interpret feedback from the environment about how well they have accomplished those activities. When they have buggy mental models, people often misdiagnose their limitations and discard or misinterpret informative feedback that could improve their mental models. Sometimes the feedback indicates that a person may have to "unlearn" or even discard a buggy mental model in order to learn, but it is very difficult to see the requirement. The difficulty is not the learner's pride, but a more literal inability to "see" the conflicting information until he or she believes it. The existing buggy mental model, by distorting cues and feedback, acts as a barrier to learning.

Progress does not simply occur in fits and starts. It may involve some backtracking to shed mistaken notions. To complicate the process, buggy beliefs may be retrieved by accident, which is a source of confusion. These beliefs have also influenced the way a person encoded experiences in the past. Simply changing one's beliefs will not automatically change the network of implications generated from those beliefs. As a result, people may struggle with inconsistencies based on different mental models that have been in use at different times.

Cognitive Transformation theory offers a set of postulates about the nature of mental models and the learning process. For a full review of these postulates, see Klein and Baxter (in preparation) and Ross et al. (2005). Here we present a few of the key postulates that guide the cognitive skill acquisition framework:

- Mental models are not unitary; people do not hold a single, all-encompassing mental model for a domain. Mental models are fragmentary. Learners have developed "chunks" of causal and other relationships pertaining to distinguishable aspects of the domain.

Table 2. General Characteristics of Stage 5 Experts

STAGE 5: EXPERT	
General Characteristics	
Knowledge	***Performance***
• How to make fine discriminations between similar environmental cues. • How to intuitively assess the situation. • How to respond to maxims or nuances based on the unique array of cues and factors in the situation. • How to intuitively respond to the situation. • How tasks and subtasks are supposed to be performed. • How equipment and resources function in the domain. • How to perceive meaningful patterns in large and complex sets of information. • What is typical and atypical for a particular situation. • A wide range of routines or tactics for getting things done. • More facts about the domain than less proficient individuals. • A huge library of lived distinguishable experiences that impact how handling of new situations. • How to set expectancies and notice when they are violated.	• Is fluid and seamless, like walking or talking; "integrated rapid response." • Is based on prior experience for both assessment and decision making. • Is automatic, and the rationale for actions is often difficult to articulate. • Relies heavily and successfully on mental simulation to predict events, diagnose prior occurrences, and assess future actions. • Consists of more time assessing the situation and less time deliberating a course of action. • Shows an ability to detect problems and spot anomalies early. • Capitalizes on leverage points, or unique ways of utilizing ordinary resources. • Reflects use of innovations and new possibilities for responding to particular situations (like leverage points). • Manages uncertainty with relative ease, by filling gaps with rational assumptions and formulating information-seeking strategies. • Reflects metacognitive skill, or the ability to self-monitor. • Shows efficient information search activities.

- Mental models are modular. People have a variety of fragmentary mental models which they weave together to account for a novel observation. In many cases people rely on Just-in-Time mental models. People are usually not matching events to sophisticated theories they have in memory. They are using fragments and partial beliefs to construct relevant mental models.
- No set of mental models is perfect and complete. Causal mental models often take the form of a story. Stories have many advantages—they are fairly clear and easy to recall and use—but they can also introduce distortions.
- Learners build their repertoires of fragmentary mental models in a discontinuous fashion. They rely on a given set of mental models to direct attention, make decisions, encode data, interpret feedback, make diagnoses, anticipate problems, and so forth. In so doing, they distort data, oversimplify, explain away diagnostic information, and misunderstand events. At some point, they realize the inadequacies of their mental models. They abandon their existing mental models and replace these with a better set of causal beliefs.
- Learning curves reflect discontinuous acquisition of cognitive skills. If researchers combine data from several subjects, they will obtain reasonably smooth learning curves because of the averaging of discontinuous curves. Individual learning curves for mental models, however, are not smooth (e.g., Lipshitz & Marmor-Pilowsky, 2004).
- Progress depends on unlearning. The better the causal models, the more difficult it is to replace them. A reasonably good mental model shapes our perceptions. As a result, the better the mental model, the harder it is to discover its weaknesses and to replace it. In many cases, learners have to encounter a baffling event or an unmistakable anomaly in order to begin doubting their mental models.

Cognitive Transformation theory appears to offer a view of the transition process that is different from traditional learning models. It suggests that in order to support the improvement of domain mental models, advanced training designs must 1) incorporate cognitive challenges found in the field of practice, 2) provide elements of a situation that develop perceptual attunement, and 3) create an immersive experience that stimulates authentic cognitive behavior from the user's point of view that is like the cognition of experts in the field.

A FRAMEWORK FOR TECHNOLOGY-BASED TRAINING OF COMPLEX COGNITIVE SKILLS

Absent effective guidelines, training systems developers have spent much time and money reproducing the most faithfully realistic experiences they could, trusting that experience would create expertise. We believe we can now shed more light on how to use simulation-based training at the right times in the learning cycle in ways that most effectively build tactical thinking skills. Here we present excerpts from the general framework that can be adapted to any ill-structured, cognitively complex domain.

A General Cognitive Skill Acquisition Framework

The general framework describes the learning process and training implications for all stages of learning in ill-structured, cognitively complex knowledge domains. The framework can be applied to a range of domains, but it is ideally suited to simulation-based training and the affordances it offers for the presentation of rich context, dynamic situations, and mechanisms for sustained exploration of situations or cases, as well as the potential for embedding instructional strategies and assessment. Using the general framework as a guide allows developers to articulate requirements for simulation-based training that will integrate learner and instructor needs, make predictions about desired outcomes, and create support for training assessment of those outcomes.

Principles for Learning Progression and Implications for Training

Experiences are a necessary, but not sufficient component for the creation of expertise. Training experiences can be a waste of time or even harmful when they don't allow sufficient opportunity for domain-appropriate mental model building or when they fail to target the right kind of challenges, support performance, and provide insights. Cognitive Transformation theory offers the following overarching principles and recommendations for providing the right kinds of experiences mixed with appropriate instructional techniques to advance the learner through the developmental stages:

Principle 1. The nature of training befitting novices is qualitatively different from training that is effective for advanced learners.

- Introductory learning. The introductory learning most appropriate for novices can often create barriers when learners transition to more advanced learning. Introducing knowledge as "tools" in early training can smooth the transition. Basic knowledge should be utilized in focused problem sets within a small but rich setting characteristic of the practice domain.
- Advanced learning. Objectives for advanced learning should be not task-focused, but centered on the cognitive challenges within tasks, development of flexible mental models, and the ability to transfer domain-specific cognitive skills to new situations.

Principle 2. People can improve their mental models by continually elaborating them or by replacing them with better ones.

- Flexible routines. Mental models are often about how to get things done. Teaching people alternative ways to achieve outcomes (Gopher, Weil, & Siegel, 1989) can provide the flexibility and differentiation needed to counter constraining mental models. Scenarios can prohibit (with realistic causes) the common way of achieving an outcome so that learners are forced to find alternatives and thereby elaborate their mental models.
- Attention management. Inadequate mental models typically guide the learner's attention to the wrong cues. Training simulations can show trainees that they do not fully understand what is important by illustrating the consequences of focusing on the wrong part of the situation.
- Messiness. Training often adds to the oversimplification of mental models. Learners are taught goal hierarchies and rules of engagement (ROEs) as if these structures were real. In fact, individuals will have difficulty with goal conflicts, not with remembering goal hierarchies. For ROEs, they will get stuck when faced with conflicting rules.
- Misconceptions. Misconceptions are frequently introduced into a learner's mental models either because introductory learning simplified concepts that are actually more complex or because prior experiences provided only a limited snapshot of a particular concept in action (Feltovich, Spiro, & Coulson, 1993). Part of advanced learning is the process of repairing these misconceptions so that learners can elaborate their mental models and understand when the simplified version of the concept applies and when the situation is not so straightforward.

Principle 3. The most dramatic performance improvements occur when learners abandon previous beliefs and move on to new ones.

- Unlearning. Scenarios should help trainees unlearn their existing and limited mental models. Effective mentors can serve this function on an individual or small group level. For larger scale training, the course or system developers should try to identify common errors and confusions and set up scenarios that expose what is wrong with the buggy mental models.
- Baffling events. A reasonably good mental model shapes perceptions and informs knowledge shields. As a result, the better the mental model, the harder it is to discover its weaknesses and to replace it. Scenarios and simulations must be designed to baffle learners and break them out of their current perceptions.

Principle 4. Learners who can assess their own performance will improve their mental models more quickly than their peers.

- Diagnosis. Scenarios and feedback should help trainees discover where they need to improve. Mentors can help on an individual level by providing personalized feedback. For larger groups of students, training technologies can incorporate descriptions of the mental models of experts. Learners can compare their own conceptualization of the situation to that of the experts in order to pinpoint areas for improvement.
- Mentors. Skilled mentors can help learners develop self-assessment skills by helping them diagnose their weaknesses and discover where their mental models are too simplistic. The Socratic method is a good example, using simple questions to force learners to think about issues that go beyond their current mental models.
- Stance. Most training programs suggest that learners should be encouraged to take an active stance. However, the form of the training often runs counter to this advice. The practice-and-feedback regimen moves the trainees through like they were on an assembly line. Cognitive Transformation shows the limitations of the practice-and-feedback regimen with regard to training cognitive skills. The training emphasis needs to be back on the learner and his or her ability to make sense of feedback.

Within these general recommendations, training interventions will have the greatest impact in cognitively complex domains when they are differentially developed and applied to suit an individual's current stage of learning. We have generated distinct training recommendations for each stage, and we would like for this to be a starting point which researchers, training developers, and instructors continuously refine.

General Guidance for Each Stage

Novice. At the novice level, the individual requires a set of rules to work within so he or she has some structure with which to guide performance and build his or her own mental models (Benner, 1984). He requires an instructor or mentor for guidance while developing experiential knowledge, and dialogue with a mentor or instructor enables him or her to make sense of the experiences (Houldsworth et al., 1997).

Advanced Beginner. The advanced beginner can benefit from an instructor or mentor directing his or her attention to certain aspects of the situation. This enables him or her to begin forming principles that can dictate actions (Benner, 1984). Coaching on cue recognition and discrimination is also appropriate and important (Benner, 1984, 2004). Further, instructors should coach advanced beginners on setting mission priorities (Benner, 1984). Scielzo, Fiore, Cuevas, & Salas (2004) suggest using diagrams in instruction to facilitate the development of accurate mental models.

Competent. Decision making scenarios and simulations are highly beneficial for competent performers. The scenarios should require the learner to plan and coordinate multiple, complex situational demands (Benner, 1984) and work on prioritizing the various demands. Because competent performers tend to lack the ability to respond to changing situational demands and instead clutch their initial plan to guide actions, training at this level should encourage learners to read and react to the evolving situation. In the context of field exercises particularly, and paper- or technology-based simulations to some extent, instructors should coach and encourage learners to follow through on senses that things are not as usual, or on vague feelings of anxiety. This type of reflection helps learners determine what cues and factors are relevant without having to rely on rules to guide them (Benner, 2004).

Proficient. For proficient-level learners, scenarios should focus on improving learners' abilities to interpret the situation and recognize courses of action that will meet the mission objectives. To this end, training interventions must concentrate on soliciting and taxing the learner's ability to grasp the situation (Benner, 2004). With regard to content, scenarios should include irrelevant and, in some cases, insufficient information to generate a good course of action. They must contain levels of complexity and ambiguity that mirror real-world situations (Benner, 2004). Benner (1984) further warns instructors not to introduce context-free principles, rules, or decision analysis techniques within the context of any training or practice at this stage; proficient learners will only be stymied if they are discouraged from using the recognitional and intuitive skills they have developed.

Expert. To continue learning, experts require unique challenges that force them to stretch their thinking, and they need complexity at a very high level in order to get those challenges. Ross, Pierce, and Baehr (1999) assert that expertise requires authentic practice in an operational setting or a close approximation such as a full-scale exercise or simulation. Unlike their less-experienced colleagues, experts tend to proactively seek their own experiences and ask for feedback. Their ability as "reflective practitioners" is very high, so they incorporate experiences well on their own. Therefore, they can benefit from structure in groups of experts to help them share and reflect on learning experiences. They may also benefit from taking on a mentoring role for more junior practitioners. Modeling their thinking for those who are less proficient allows experts to reflect on their own mental models.

A COGNITIVE SKILL ACQUISITION FRAMEWORK FOR TACTICAL THINKING

The framework adapted to the tactical thinking domain specifies five stages of cognitive development for tactical thinkers based on eight tactical themes[1] generated by the Think Like A Commander program of research and training (Lussier, Shadrick, & Prevou, 2003). For each of the five developmental stages, the tactical thinking framework provides implications for TDS design and appropriate instructional strategies to foster the learner's mental model development. In addition, dominant indicators of proficiency are provided to assist instructors in judging the level at which their students are operating. Here we provide an excerpt from the Competent performer stage as an example.

Competent Individuals

Table 3 presents the tactical thinking profile for learners in Stage 3. Accordingly, we offer the following guidance for training individuals at this level:

Key Components of TDS Design. Tactical Decision-Making Simulations for competent performers should enable continued development of Asset, Mission, Enemy, and Terrain mental models, but in the context of the Consider Timing and Consider Contingencies cognitive processes. In other words, scenarios should present situations where success relies on the timing and sequencing of the operation, planning for contingencies, and adapting contingency plans as the mission progresses. Specifically:

- Scenarios should introduce surprises during the execution of missions to provide practice in rapidly responding to the changed situation.
- Scenarios should present conflicts that require prioritization of mission tasks.
- Mission orders should incorporate strict time requirements, and the scenarios should build in realistic timing of force movement, engagement with the enemy, and so forth. If success relies on accomplishing an objective by a particular time and learners are forced to make judgments about how long the prerequisite tasks will take, then good feedback about those timing judgments will be available.
- Scenarios should require proper sequencing of tasks in order for the learner to accomplish the mission.
- Scenarios should introduce the utility of non-organic and non-military assets.

Instructional Strategies. At the competent level, instructors play a key role in mental model development, but their participation at the competent, proficient, and expert levels is not required as persistently as it is for novices and advanced beginners. In lieu of an instructor, feedback can be delivered by developing expert responses against which learners can compare their own performance. Also, feedback can be generated within the TDS system by illuminating situational cues, factors, or demands that should have prompted learners to change their approach or move to a contingency plan. Regardless of the instructional medium, the following issues should be addressed with individuals at the competent level:

- Prior to execution, contingencies. What are the different ways the plan could play out, and how would the learner know if that were happening?
- Prior to execution, the enemy. What might he be attempting to do, and why? How might the learner assess the enemy's objectives as the situation plays out? What information should the learner be seeking?
- Prior to execution, terrain. What are the critical terrain features on the battlefield? How might they

[1] The eight themes for tactical thinking are: Focus on Mission and Higher's Intent; Model a Thinking Enemy; Consider Effects of Terrain; Know and Use All Assets Available; Consider Timing; See the Big Picture; Consider Contingencies and Remain Flexible; and Visualize the Battlefield.

Table 3. Tactical Thinking Profile for Stage 3 Competent Performers

- Mission. Analyzes what has to be accomplished by own mission in order to accomplish intent. Differentiates priorities in the mission order.
- Enemy. Regards the enemy as intelligent and dynamic, and can generate general suspicions about the enemy's objective and course of action.
- Terrain. Recognizes effects of terrain on courses of action, and incorporates terrain features into plan.
- Assets. Understands how organic assets can be applied to overcome enemy capabilities and accomplish the mission. Projects forward as to what other assets might be needed.
- Timing. Understands timing and sequencing in general terms, but is unable to time and sequence successfully in a particular mission.
- Big Picture. Sees the larger picture especially with regard to time horizons for own unit. Adept at considering what resources will be necessary at future points in the mission and at future locations on the battlefield. Is aware of adjacent and higher units and their missions, but does not incorporate that awareness into assessment or actions.
- Contingencies. Considers contingencies and projects how the operation may play out during planning, but in execution adheres to original or contingency plan even when the situation calls for adaptation of the plan.
- Visualization. Visualizes first-order consequences only.

impact both friendly and enemy courses of action? How might terrain be leveraged and used against the enemy? How might the enemy leverage terrain features and use them against friendlies?

- Mission plan. Why did the plan break down? What should have been the early indicators that plan wouldn't play out as intended?
- Situation. What were the cues and factors available? How might they have been interpreted?
- Timing and sequencing. What issues regarding timing and sequencing needed to be considered, and why?
- The Big Picture. What was higher headquarters trying to accomplish? What was the learner's role in accomplishing the larger mission? Did the learner contribute in useful ways to the larger mission?

Dominant Indicators of Proficiency Level. Heightened planning is the hallmark of the competent stage. An individual performing at this level in tactical thinking is likely to show the following types of behaviors:

- Is able to predict immediate futures, and therefore takes a planful approach (Benner, 2004).
- Experiences confusion when the plan does not progress as predicted (Benner, 2004).
- Experiences anxiety that is specific to the situation as opposed to generalized (e.g., am I doing this right with regard to this part of the situation?) (Benner, 2004).
- Differentiates mission priorities.
- Deliberately analyzes what has to occur in order for intent to be achieved.
- Considers trade-offs of using assets for various purposes and of keeping a reserve.
- Projects what other assets might be needed as the mission progresses.
- Generates ideas about what the enemy might be thinking and what his objective might be, but does not have a specific assessment that drives his decisions.
- Considers the enemy's capabilities in the context of the terrain and other situational factors.
- Incorporates terrain features into the plan and considers the effects of the terrain on assets employed or needed.

CONCLUSION

The purpose of the cognitive skill acquisition framework summarized in this paper is to guide the development and implementation of simulation-based training in complex, ill-structured domains such as tactical thinking. It is intended as a starting point that training professionals and researchers can continuously refine and extend as the advanced learning process becomes better understood through research and as simulation-based training technologies are iteratively designed, implemented, and assessed.

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