The goal of this white paper is to encourage a dialogue that will identify and organize learning science findings and technologies to help the Army train soldiers and develop leaders. The objective of the science and technology identified is to accelerate learning and performance while maximizing effectiveness and minimizing resource requirements. The Army’s current ISD - SAT training design strategy is based on learning models that are approximately 30 years old. If we retain the best of the past while adding the most effective current, research-based approaches we may achieve needed increases in both effectiveness and efficiency.

Overview
The first part of the paper will provide a very brief description of the three learning science models currently available in the social sciences to support training and leadership development. Then the discussion will turn to a description of some of the key learning factors and features of the most powerful training analysis, design and development models that appear to be based in the learning sciences. The “best practice” use of these models by other large scale institutions such as other branches of the military and large corporations will be briefly discussed. Next the discussion focuses on how individual, generational and cultural differences may (or may not) influence learning, motivation and performance during and after training. Finally, the paper concludes with recommendations for identifying critical features of the next generation of Army learning and performance systems along with conservative estimates of increases in effectiveness and efficiencies that might accompany their adoption.
Introduction

In the past two decades the National Research Council (NRC) has pursued a topic similar (but not identical) to the one addressed in this paper and have published a number of book size reports on learning, training and performance. The NRC has focused on the results of basic and applied research and evaluation in all of their reports.

The initial NRC strategy was to review the evaluation evidence for a number of “best practices” 1,2 but soon changed their strategy to focus instead on “the implications of fundamental psychological or social psychological processes underlying performance” 3,4. The change was apparently due to the gradually developed view that best practice methods are not often effective - perhaps because they tend to be developed and implemented locally, fail to generalize and largely ignore well designed and relevant psychological process research which, if incorporated, would increase their effectiveness.

At this juncture, there are approximately 50 learning and performance models (http://tip.psychology.org/theories.html) and over 100 instructional design models that compete for attention (http://carbon.cudenver.edu/~mryder/itc_data/idmodels.html).

This report will adopt the process approach suggested by the NRC. It begins with a very brief review of the three primary theories of learning that underlie much of the basic and applied research.

Three Learning Science Models:

In the past century, social scientists have adopted three different theories to understand learning. Each of the theories is connected to a number of “spin off” instructional models that focus on some but not all elements of the parent. While the models have developed roughly in the order listed below, some elements of all of these models persist today in training and educational design.

- Behavioral models 5 used a “black box” metaphor for our mind. Behaviorists attempted to gain insights about learning from the way that unobservable mental processes modified information (stimuli) input-output relationships. The careful measurement required by behaviorism helped develop clear specification of objectives, motivational components of treatments (reinforcement) and their performance consequences.

- Cognitive models 6 tended to use the linear computer as a metaphor for the mind. They assume that the mind manipulates symbols (through language) using mental “programs” that can be learned. Essential to the cognitive model are self-regulating metacognitive strategies such as planning and self-monitoring that help adults manipulate information and construct knowledge to achieve learning goals. From the perspective of cognitive models, effective instruction trains learners to develop learning strategies that help them achieve have, among other benefits, helped us provide effective instruction that supports the learning of conscious conceptual knowledge.
Connectionist models have adopted a metaphor for the mind as a series of parallel, interconnected, multilayered, neuronal-like subsystems or modules that work simultaneously but in parallel to achieve performance goals. Connectionist-based training methods focus on methods that support the gradual tuning and automating of context-bound mental modules that are implemented when specific internal or external conditions are present. Connectionist models have helped us understand how to support the development of automated and unconscious knowledge.

Applying Science of Learning Models to Training and Performance Improvement:
Each of the models has contributed valuable insights about learning and performance. Yet, past attempts to apply science of learning models directly to training have achieved mixed results. Behaviorists found that effective, complex learning required more than a “black box”, objectives and schedules of reinforcement. Cognitivists have learned gradually that while people may use their own mental programs to construct their own somewhat idiosyncratic conceptual knowledge about topics, prescribing minimally guided learning strategies in problem-based or simulated settings does not result in effective learning strategies for most adults. Connectionists struggle with the need to identify some type of mental integrating process that can direct and regulate learning and performance.

To capture the effective features of the models and pull them into a current training design system we turn next to an analysis of three types of variables or factors that are common to nearly all of the models.

Identifying Effective Prescriptions for Training Analysis, Design and Development:
A review of the large number of psychological processes that have been the subject of research over the years is outside of the scope of this paper. However, a number of research reviews in the past two decades have suggested that three major types of factors account for most learning from instruction: 1) Individual and group traits; 2) Learning task types; and 3) Training methods. The goal of an effective training design system is to provide prescriptive guidance such as:

- For trainees with X traits;
- Who need to succeed at learning tasks of type Y
- Provide training methods of type Z

Each of these factors will be briefly discussed and then related to the type of prescription described above for training analysis and design systems.

Individual, Group and Generational Traits Influencing Learning and Motivation
The best evidence to date is that three characteristics or traits of adults that have been found to influence their learning in research on instruction. Those traits are general ability, prior knowledge and self efficacy. Soldiers are selected with ability levels that are adequate to learn under many training conditions so general ability will not be considered further. Training can usefully be adjusted to support individual and group...
differences in the two remaining factors, prior knowledge\textsuperscript{12} and self efficacy\textsuperscript{13}. Two generalizations about individual differences receive consistent support in the research on learning from training:

- \textit{Prior Knowledge}: The less knowledge and experience trainees have learned about the subject matter or objectives of the training, the more guidance they need to learn and perform -- and vice versa. Experts do not need extensive support to learn new information in their area of expertise. Novices require strong guidance as they learn to be soldiers.

- \textit{Self-Efficacy}: The less self-efficacy trainees have about their capability to learn and perform the objectives of the training, the more motivational support they require. Similarly, overconfident trainees may require training methods that encourage them to develop new knowledge.

Many other individual and group differences have been studied and a few have many supporters based on intuitive beliefs in their effectiveness. Many social commentators have claimed that the younger generation of soldiers have shorter attention spans and learn best from fast paced, interactive multimedia games or simulations. While this seems intuitively correct, there is no scientific validation for the claim. A recent, systematic, large scale study of individual, team and generational differences in business organizations not only failed to identify generational differences, it reported common factors accounting for the performance of adults at all age levels\textsuperscript{14}. Similarly, claims that adults have different “learning styles” have not been supported despite a very large number of studies on this topic over many years\textsuperscript{15}.

\textbf{Learning Task Types}: Often ignored in discussions about learning is the long-standing claim that there are two broad classes of learning tasks and that each type requires different instructional methods or support:

- \textit{Declarative tasks} where conscious, conceptual knowledge about “what and why” are required to succeed. Declarative knowledge tends to take the form of concepts (“What is this?”); processes (“How does it work?”); and principles (“What causes it to happen?”). Declarative learning is committed to memory in such a way that it can be recalled when it is needed.

- \textit{Procedural tasks} where “when, where and how” is required to succeed. Procedural knowledge tends to take the form of sequences of actions and decisions that, when implemented under appropriate conditions; achieve simple and complex performance goals. Procedural knowledge is intended to be practiced until it automates and can be implemented without taking up space in working memory.

To some extent, different science of learning models can be said to favor one or the other type of learning task. Cognitive models tend to focus on the learning of declarative knowledge in the form of concepts, processes and principles about warfighting topics.
Behavioral and Connectionist models tend to emphasize the learning and gradual automation of unconscious mental and physical procedural routines that support the actions and decisions necessary achieve warfighting performance goals while overcoming limits on working memory.

**Task Analysis: The Dilemma of Automated Expertise:**
Most of the information provided in Army training is captured from subject matter experts. This information is gathered during task analysis interviews and narratives in the form of “self reports”. Yet one of the consistent findings from the science of learning is that while experts have highly accurate and very efficient strategies for achieving problems related to their expertise, they are also largely unable to describe the strategies they use. Evidence suggests that when asked how to perform a task experts unintentionally leave out approximately 70 to 80 percent of the information needed by novices to achieve objectives. The result is that trainees who leave training and join their units in the field require continuing training and are forced to learn from inefficient ‘trial and error’ experiences. To overcome this problem, an effective new strategy for capturing both routine and complex expertise strategies has been developed called “cognitive task analysis”.

- **Cognitive Task Analysis (CTA)** should be combined with traditional task analysis to capture automated and unconscious procedural knowledge from subject matter experts about their highly effective and efficient performance strategies. Effective training requires accurate and complete declarative and procedural information necessary to achieve all warfighting tasks. CTA slightly increases the front end effort required to design training with the benefit of decreasing training time and reducing trainee errors.

The evidence from the science of learning suggests that each of these two types of learning tasks requires different training methods for trainees who have different levels of prior knowledge. Thus, the discussion turns next to the third factor, training methods.

**Training Methods:**
Training methods can be defined as events that are intended to support psychological learning processes or methods required to achieve learning objectives by trainees who are unable or unwilling to provide them for themselves. For example, all learning of new concepts (a declarative task) by lower prior knowledge trainees is aided by examples. Giving feedback during practice is a method intended to support trainee monitoring and correcting of their learning. All training methods are not effective for all trainees and tasks so the goal of a learning science is not only to describe effective methods but to specify their match with trainee traits and learning tasks.

Past research has helped describe the psychological processes that must be supported during learning and the way that instruction can provide guidance. One of the most promising recent approaches can be found in a review of several research-based training design systems by David Merrill with support from the American Society for Training.
and Development. His review focused on five generalizations about the type of trainee experiences that appear to be essential for successful training:

Learning from training is increased when:

1. Trainees prior knowledge is activated as a foundation for new knowledge
2. Trainees are engaged in solving authentic, real world problems
3. New knowledge is demonstrated to the trainee
4. Trainees are required to apply new knowledge and receive feedback
5. New knowledge is integrated into the trainee's world

All of these prescriptions are useful for every training lesson or course and, if adopted, each generalization describes criteria that must be achieved by all training methods for every lesson or course. For example, Merrill implies that we must always activate prior knowledge and that even though a rich variety of ways exist to achieve activation of prior knowledge (e.g. examples, metaphors, analogies and stories), effective methods must function to activate relevant trainee experience and help them apply it to new learning. Similarly, whether demonstrations are provided live by experts or asynchronously by multimedia animation may be less important than whether they are accurate, complete and clear to the trainee. Similarly, a variety of practice and test formats are valid provided that they meet measurement requirements, reflect the type of knowledge being learned and are gradually integrated into guided, “whole task” practice exercises that help transfer new knowledge and skills to the field.

Merrill specifically avoids prescriptions that are generally accepted such as the requirement to direct trainee learning by providing an objective that clearly describes what will be learned, the conditions where it will be applied and any relevant time or accuracy standards.

When integrated into the system described in this paper, we arrive at a series of more complete prescriptions such as:

- For low prior knowledge trainees who must learn procedural knowledge, provide strong guidance in the form of clear objectives, examples from their past experience with similar procedures, demonstrations based on CTA descriptions of the task, require part and whole task practice using authentic problems with immediate feedback that helps them correct their procedures and transfer them to the field.

- For high prior knowledge trainees who must learn procedural knowledge provide minimal guidance in the form of clear objectives, a CTA description (or demonstration) of a procedure for accomplishing the objective and a whole task practice problem they can use to develop their own version of a procedure for accomplishing the objective21.
Declarative tasks may have slightly different prescriptive rules. Science of learning studies indicate that memory for concepts, processes and principles are the key goal of declarative learning. Wherever knowledge must be applied, procedures are involved. Thus declarative task learning prescriptions require a similar list of methods that are required to support recognition and recall of concepts, processes and/or principles. Most training will require the learning and integration of both declarative and procedural knowledge.

**Critical Features of Army Training Design Systems**
The next challenge is to integrate powerful science of learning prescriptions to upgrade the Army training design and development system. Merrill and others have cautioned us to separate design, development and implementation of training because different problems must be solved at each stage from early blueprint to the decision about media for delivery of a completed training product. One possible format for a training design system that incorporates prescriptions based on psychological learning processes might look like the following:

**Guided Experiential Learning Design**
A list of the components of a training design for all courses and lessons for all learners and tasks required by the Army might ask for a blueprint for how to achieve the following:

1. **Objective:** What actions, conditions and standards will you learn in this course (lesson)?
2. **Reasons:** What are the benefits to you and your unit when you learn and apply? What are the risks of not learning or applying?
3. **Overview:** How is this course (lesson) structured and what training strategy is used?
4. **Declarative Knowledge:** Here are definitions and examples provided in this lesson of concepts, processes and/or principles from a CTA - you need to learn and be able to remember later.
5. **Procedural Knowledge Demonstration:** In this lesson, observe this CTA based demonstration because you will be asked to apply it yourself after it is finished.
6. **Problem Solving and Feedback:** Now solve problems or objectives (derived from a CTA) that are similar to those you will encounter in the field. Use the procedure you observed in the demonstration. As you practice you will receive feedback about the parts of your strategy that are effective and parts that need to be revised.

**Effectiveness and Efficiency Gains with Guided Experiential Learning Systems**
Merrill describes a comparison of three types of training design for the same task – an unguided, discovery design that was compared with a very well funded training that used an ISD-type design and distance delivery and a guided experiential learning approach. He reports that the guided experiential learning approach described above resulted in a 50 percent gain in learning and performance in about 55 percent less time when compared to the unguided approach - and approximately a 20 percent learning gain with a 15 percent time savings over an ISD-type approach.
Training and Performance Needs Analysis – Army Performance Improvement

Most of the professional associations representing trainers and performance improvement specialists have recently adopted a new technology for needs analysis. Past approaches tended to assume, often incorrectly, that training was necessary to correct a problem or achieve either collective or individual performance goals. The current approach makes the assumption that performance gaps are caused by at least three very different factors: 1) Knowledge gaps (requiring training); and/or 2) Motivational gaps (requiring motivational solutions); and/or 3) Organizational design and process gaps. This model has been adopted by both the Navy\textsuperscript{23} and the Coast Guard\textsuperscript{24} with positive results.

This “gap analysis” approach has been called “Human performance technology” (by the International Society for Performance Improvement\textsuperscript{25}) or “Human performance improvement” (by the American Society for Training and Development\textsuperscript{26}) but regardless of the name, the approach requires that all analysis begin with a collective and/or individual performance goal and a strategy for measuring goal achievement. In the next phase, the gap between the ultimate goal and current progress towards the goal are measured. In the third phase, an analysis of the contribution of the three possible causes of the gap (knowledge, motivation and organizational process) is conducted. In phase three interventions are selected, designed, developed and validated that have promise to close the gap. In phase four, implementation occurs at all levels required to close the gap and then in phase five, evaluation measures the local success of the programs implemented and their effect on the larger gap\textsuperscript{27}.

**Model for Army Performance Improvement System**

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<th>Phase 1</th>
<th>Phase 2</th>
<th>Phase 3</th>
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<td>Mission Goal Measured and Performance Gap Established</td>
<td>Knowledge Motivation Organizational Causes Analyzed</td>
<td>DOTMLLPF Solutions Selected and Created</td>
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Phase 4 Implementation of DOTMLLPF solutions

Phase 5 Evaluation of Impact on Gap and Revision
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**Conclusion;**
This paper ends where an effective performance design system should begin – with a system that permits effective and efficient analysis of a mission problem that result in systematically identified solutions. Training is an important solution to many (not all)
performance gaps. Obviously, full performance analysis requires a technology for identifying and solving both motivation and organizational design and process causes of performance gaps.

The goal of this white paper was to describe a prototype training design model that would be based securely on evidence from the science of learning. While readers may imagine many prescriptions or design features not described in this report, the attempt was made to offer a format for considering the key components of design that have promise to accomplish the goal of this exercise - identify and organize learning science findings and technologies that will help the Army train soldiers and develop leaders with the objective of accelerating learning and performance while maximizing effectiveness and minimizing resource requirements. Alternatives should be firmly based on evidence from the science of learning and show promise of meeting the Army’s needs.

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