DIGITAL SKILL LEARNING USING CONSTRUCTIVIST TRAINING METHODS

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ABSTRACT

The Objective Force will present many challenges for tomorrow's soldier. The purpose of this study was to assess the effectiveness of constructivist learning techniques for training soldiers in Military Intelligence (MI) on the digital battlefield. Exercises and test instruments used in current MI courses at Fort Huachuca were adapted for application by school instructors. The constructivist approach was compared with conventional, lecture-based MI training. Constructivist scenarios were designed to require soldiers to operate the All-Source Analysis System-Remote Workstation (ASAS-RWS) and to achieve tactical dominance via the use of superior awareness. The research team developed Practical Exercises (PEs) requiring soldiers to solve problems, develop/send/receive specialized queries, and develop time-sensitive MI products. A major goal was to train soldiers to acquire and apply digital skills in response to changing and ambiguous battlefield situations. The group (n=18) taught using constructivism performed significantly better than conventionally-trained controls (n=32) on the performance-based PE (F (1,43)=11.59, p<.05). Both groups mastered all terminal learning objectives. As compared with the constructivist-trained group, soldiers trained using the conventional method reported higher levels of mental demand, time stress, and effort. The constructivist group covered more material in less time than those taught using the conventional method yet they did not perceive an increase in workload as measured by the NASA-TLX. Results suggest that constructivist training approaches provide an effective means for teaching digital and analytical skills on the future battlefield.

BIOGRAPHICAL SKETCHES

Jerry Childs is Director, Training and Performance Engineering with TRW where he provides human performance and training support to government and commercial contracts. He has 26 years experience in the training industry and holds a PhD in Engineering Psychology from Texas Tech University. He has served on I/ITSEC subcommittees and is a member of the Aviation Industry CBT Committee (AICC).

Brooke Schaab is a research psychologist with the U.S. Army Research Institute's Advanced Training Methods Research Unit. Current research interests include training soldiers to excel using information technology. She holds a PhD in Human Factors Psychology from Old Dominion University.

Norm Blankenbeckler served on active duty in a variety of tactical intelligence assignments. Highlights include service as the Operations Officer (S3) of the 525th Military Intelligence Brigade (Airborne), during Desert Shield/ Storm and service as the Senior Intelligence Officer (G2) of the 1st Cavalry Division during testing and acceptance of the All-Source Analysis System (ASAS). He is currently a Senior Training Developer with TRW Systems and has been a key participant in US Army digital training studies.

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BACKGROUND

Objective Force Effects on Soldier Proficiency

The Objective Force is the Army's future total combat capability: organized, manned, equipped, and trained to be more strategically responsive, deployable, agile, versatile, lethal, survivable, and sustainable across the full range of military operations from major theater wars through counterterrorism to Homeland Security. To realize the full capabilities of the Objective Force (Figure 1), today's Army must provide soldier training that yields flexible and adaptable problem solvers who function well on teams, can apply what they know, and can rapidly find solutions for what they don't know. These prerequisites will enable our forces to see first, understand first, act first, and finish decisively at strategic, operational and tactical levels (Department of the Army, 2002).

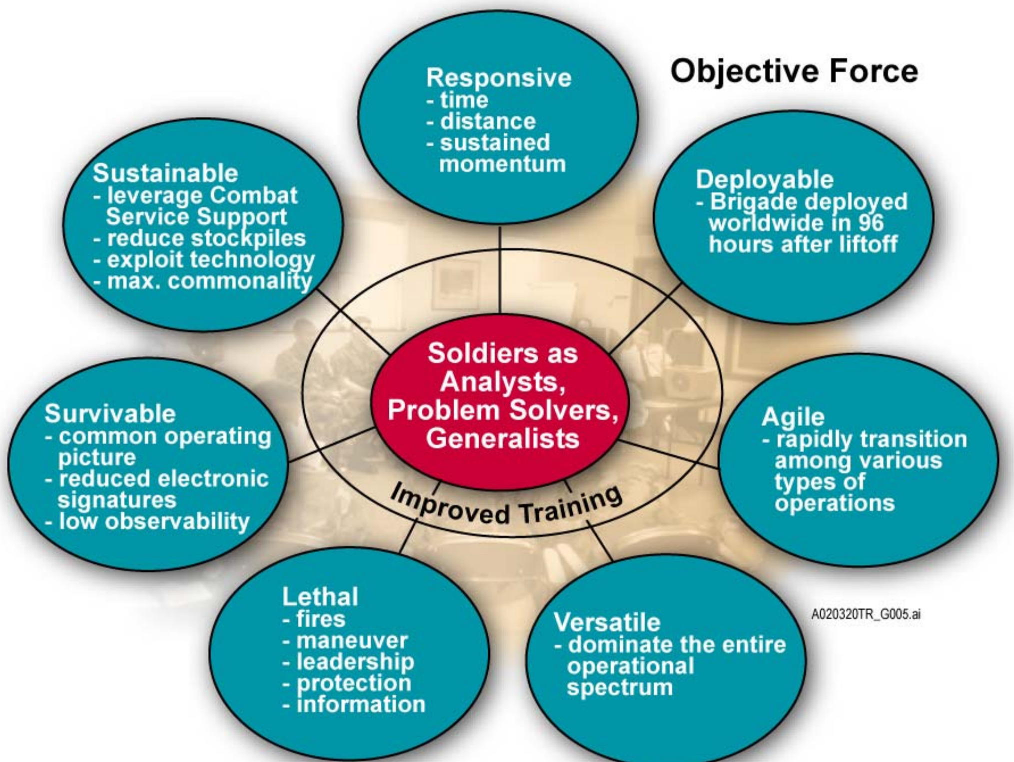

Figure 1. Soldier training and the Objective Force.

At least two factors associated with global implementation of the Objective Force change the demands placed on tomorrow's soldier. First is that the emerging environment includes an *adaptive threat* taught to ignore conventional military doctrine and to fully exploit our vulnerabilities at any cost. This enemy is a "free thinker," often motivated by principles of terrorism and unconstrained by policy and doctrine. To defend against this threat, our soldiers must be taught abstract reasoning, deductive and inductive logic, decision-making skills, judgment, situation awareness, and other higher-order, cognitive skills. Such training, historically reserved for senior leadership, must be pushed to lower echelons. Mental rehearsal, practice, collaboration, and frequent self-assessments are needed to promote the development of cognitive skills and to enable soldiers to think and perform multidimensionally. These skills require a learning environment that differs somewhat from today's conventional military classrooms. Second, the new combat environment presents high lethality with very significant consequences. Nuclear, biological, and chemical (NBC) weapons in the hands of the adaptive threat require unprecedented levels of force speed, accuracy, and flexibility.

Complex digital systems challenge soldiers in their use both from the standpoint of procedures for effective operations, and, more importantly, of how to use the systems to gain a competitive advantage on the battlefield. Research shows that combining digital training and real-world complexities has been successful in advancing adaptable thinking at the command level (Ross & Lussier, 1999). Structuring training to facilitate problem solving, decision making, and situational awareness on the battlefield remains a challenge for the Army. Additionally soldiers must learn increasingly complex communications and processing systems. In the Objective Force, these requirements cannot wait for the soldier to mature and develop. They must be mastered by the entry level soldier.

STUDY APPROACH

This research examined a constructivist training method that advances soldiers' capability to adapt to unexpected task and unpredictable mission conditions in such a way that they reduce workload and function at high levels of competency. The constructivist method builds on existing knowledge by using training experiences embedded in a real-world context (Fosnot, 1996; Ross & Yoder, 1999). Learning is interactive with other trainees and the instructor, with the instructor intervening when the trainee is no longer making progress. This intervention uses "scaffolding" in the form of questioning, demonstrating, discussing, or providing instructions that encourage the trainee to think about the situation more deeply and adaptively. While constructivist methods have shown significant promise in the literature (Black and McClintock, 1995; Edelson, Pea, and Gomez, 1995; Resnick, 1996; Duffy and Cunningham, 1996) no previous attempt has been made to empirically investigate such methods using enlisted soldiers in a Training and Doctrine Command (TRADOC)-approved curriculum at the entry level.

Jonassen (1994) has set forth eight characteristics of constructivist learning environments. These are shown in Table 1 and were incorporated into our methodology for students assigned to the constructivist group.

Table 1. Constructivist Learning Environments (adapted from Jonassen, 1994).

Constructivist Learning Environments
1. Provide multiple representations of reality
2. Represent the complexity of the real world
3. Emphasize knowledge construction (vs. knowledge reproduction)
4. Employ authentic tasks in a meaningful context (vs. abstract instruction out of context)
5. Provide learning environments that represent real-world settings
6. Encourage thoughtful reflection on experience
7. Enable context-and content- dependent knowledge construction
8. Support collaborative construction of knowledge through social negotiation (vs. competition among learners for recognition)

Sponsored by the Army Research Institute (ARI), this effort was part of a research initiative to assess digital skill acquisition and retention (Schaab and Dressel, 2001; Childs, Blankenbeckler, and Dudley, 2001). The study focused on entry-level Military Intelligence (MI) analysts learning to operate the All-Source Analysis System Remote Workstation (ASAS-RWS), a digital intelligence processing and communications system for assisting the MI soldier with basic analysis, storing, processing, and display of information relevant to mission success.

Current Army training methods focus on delivering a predetermined program of instruction primarily via instructor-led lectures and practical exercises (PEs). While useful for teaching procedural skills, PEs generally are not designed to provide an understanding of *how* those skills relate to combat effectiveness. For example, entry-level soldiers are taught basic procedures for operating computer-based equipment, but instruction frequently is not linked to its operational use. Soldiers therefore may acquire "knobology" skills without knowing *how* the system functions as a tool to enhance mission accomplishment through increased situational awareness and information transfer.

The research reported here was designed to purposefully implement and evaluate a constructivist training method that integrated operational knowledge with digital system skills. As compared with conventional MI instruction, training which combines procedural knowledge with mission-related tasks was expected to better prepare soldiers to be adaptable and flexible users of ASAS-RWS and other digital systems. To permit such training, the research team was tasked with accomplishing two major goals. First, senior leadership's approval had to be obtained to implement a constructivist learning strategy at the MI school. This was coordinated among senior leadership of the school, TRADOC, and ARI. Second, the support contractor was tasked with modifying PEs to enable procedural training approaches to be integrated with mission-related knowledge as part of Advanced Individual Training (AIT) at the MI school. Our MI subject matter expert (SME) worked closely with MI School instructors to purposefully develop scenarios, exercises, and tools to assess the effectiveness of constructivist methods as compared to the conventional MI curriculum.

METHOD

Our research team included an ARI behavioral scientist with applied research experience, as well as a former Army Tactical Intelligence Officer, knowledgeable in the effective application of ASAS-RWS data on the battlefield and familiar with constructivist training strategies. This team worked directly with MI faculty and training managers to communicate research requirements, tailor instructional methods/tools, assist MI instructors in applying constructivist methods, build training effectiveness metrics, and assess student proficiency on unit exams. Entry-level, enlisted MI soldier performance was compared using two training methods for teaching ASAS-RWS operations within the 96-B curriculum:

<u>Conventional Method (Control)</u>

- Used by instructors within the current MI curriculum
- Focused on system operating procedures
- Focused on individual learning needs
- Instructor's role primarily lecturer and evaluator
- Lecture-based supplemented by "canned" exercises
- Scheduled, fixed-time instructor interventions

<u>Constructivist Method (Treatment)</u>

- Tailored to apply to individual students' needs relative to their learning levels
- Focused on relating operating procedures to mission success/failure
- Minimal lecture supplemented by tailored instructor inventions
- Focused on both individual and team learning needs
- Scenario-based problem solving focused on cooperative learning
- Instructor's role as mentor/coach to provide guided practice
- Proficiency-based progression building on previously learned content

A two-group post-test only design (Figure 2) (Childs and Bell, 2002) was used to collect the data. Because of military training requirements, it was not possible to randomize the assignment of students to groups. However, experience/demographics data were collected and analyzed to determine any *a priori* differences between groups. SMEs reported that students were drawn from similar populations with respect to their knowledge of MI.

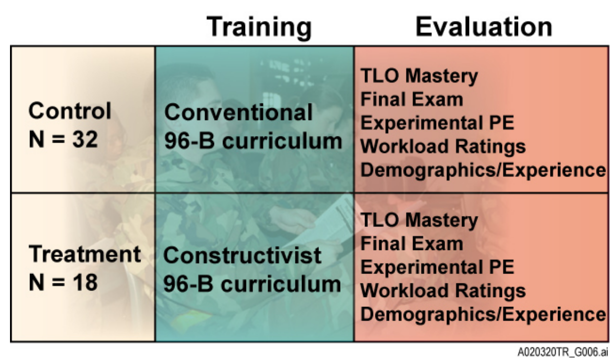

Figure 2. Study design.

Training time for the two groups was pre-arranged to be equivalent. MI training management and faculty were concerned that use of the constructivist method might require more instructor involvement, and hence more training time, than conventional methods. However, after learning the basic ASAS operating procedures, the constructivist group, using scaffolding techniques to build on prior knowledge and collaborative learning, actually moved through the curriculum more rapidly than the controls who followed a fixed-time curriculum.

For the constructivist-trained group, situational awareness and complex problem solving were emphasized within the PEs developed by our team especially for those purposes. The PEs are contained in Childs, Blankenbeckler, and Dudley (2001) and were designed to assist the instructors in calling attention to relevant cues, missing or misleading information, and desired response sets relative to the mission demands. Terminal Learning Objectives (TLOs) aimed at providing mission-essential competencies remained the same for both groups. All training incorporated PEs specifically designed and developed by the research team to reinforce skills and to assist instructors in bridging “knobology” skills with combat-oriented proficiency.

Instructors

Three instructors participated in this study. They were current or former Non-Commisioned Officers (NCOs) with an average of 11 years experience including MI and ASAS. The research team worked with instructors to impart the skills necessary to apply constructivist methods. This included a four-hour training session demonstrating the constructivist approach (Schaab and Dressel, 2001).

Student Participants

Forty-eight enlisted soldiers, most with only basic Army experience, volunteered for this research. Several of the soldiers had prior military experience in dissimilar occupations such as the motor pool and infantry. Experience in MI was meager and none had used digital equipment to perform the intelligence analyst job. Details about student participants are shown in Table 2. On average, students held a high school diploma, were 21-year old privates, and had slightly more than 1 year in service.

Note: Scores from the two sergeants were not used, as they were not entry-level.

Course/Class Description

Traditional AIT for MI analysts requires 83 training days, with the first 65 days devoted to basic skills, including performing analyst tasks using nondigital equipment (e.g., paper maps and acetate overlays). Days 66-72 are dedicated to training on the ASAS-RWS, a digital system used as a communications center for inbound and outbound messages and for creating map overlays of the area of interest (AOI). MI analysts plot information received from other digitized systems and from organic sources (e.g., scouts on the ground) to depict the locations of friendly and nonfriendly units and terrain features in the AOI. This accurate and timely picture provides a common view of the AOI for additional analysis and planning. For example, weapon ranges could be estimated and minimal travel time calculated based on terrain features and weapon types.

Table 2. Student Demographics.

	Mean	Min	Max	Std. Deviation
Education	12.78 years	12 years	16 years	1.31
Age	21.15 years	18 years	29 years	3.07
Time in Service	12.85 months	6 months	63 months	13.94
	Frequency			
Rank	40 privates	6 specialists	2 sergeants	

Three classes, each consisting of 15-16 male and female soldiers and a primary instructor, participated in this research only during days 66-72, the time reserved for RWS training. Each of three classrooms contained 15 “plug-and-play” computer systems and one trainer's module that projected the computer display on a large screen in the front of the classroom.

Training Methods

Conventional method. Two classes (n = 32 students) followed the conventional style of lecture, demonstration, and PE, with the emphasis placed on learning how the system operates. The last day of training included an application requiring the soldiers to use their knowledge of the system to develop a digital map depicting the battlefield.

Constructivist method. One class (n = 16 students) received a brief introduction to the digital equipment and on-line manual followed by presentation of the specially designed PEs. Implementation of this constructivist training method used a series of short PEs developed by our Senior SME to stress analysis and problem solving. The PEs built upon one another and prior learning in the course to accomplish the required tasks. Soldiers worked in teams of 3 to 5 members to define the goal of a PE and formulate a plan on how to resolve the problem. When one part of the PE was completed, individual students debriefed the instructor, and sometimes other teams then moved forward at their own pace. No training time was added to the program of instruction. The responsibility for learning the material was shifted from being centered on the instructor to being centered on the soldier (Figure 3).

As with traditional training, the role of the instructor remained a critical link in student-centered learning. After basic information was delivered, the instructor circulated throughout the training facility to coach, suggest, and provide insights about how to address difficulties that arose during the PE. The instructor had to be skilled in behaviors that assisted soldiers to learn on their own. For example, when a soldier had difficulty framing a problem regarding the danger posed by the enemy, the instructor coached the student to think through the problem. The instructor said something like: "It sounds to me like you're trying to determine what enemy assets pose the greatest threat to your unit. What are some of the things you look for to determine threats?" This type of coaching helped the student clarify the problem and gather information to solve it. The instructor for the constructivist-trained group was provided with 3 hours of training by our team and practiced using these techniques prior to teaching the class.

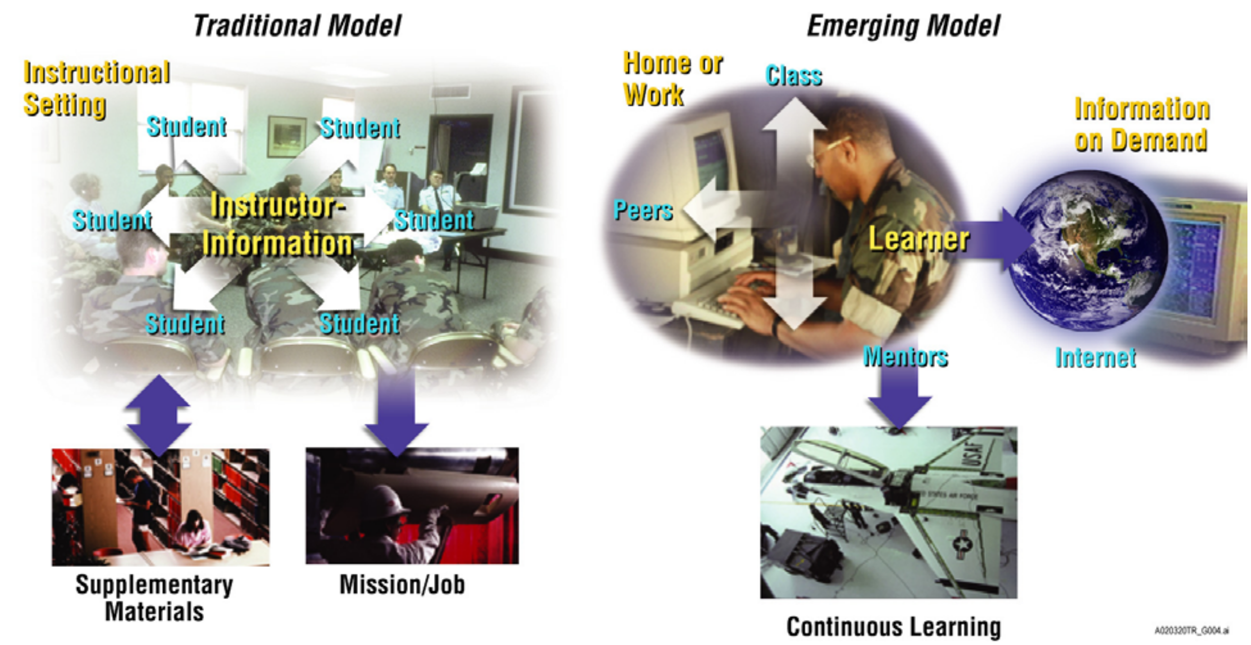

Figure 3. Traditional vs. Learner-centered approach.

Practical Exercise and Final Exam Performance

At the conclusion of the course, each soldier applied newly acquired skills to an "experimental" PE about an unfamiliar situation. The learning objectives remained the same, but the map and database changed and the problem to be solved centered on battle-damage assessment rather than on defensive tactics. Instructors scored the experimental PE by assessing the accuracy of each student in depicting or identifying key information. Soldiers were told that the PE was to help them prepare for their final examination and that the PE would not be used in determining their success in the class. This PE was followed by the schoolhouse final exam.

Soldier Background Information

Soldier background information was collected via a self-report questionnaire that included items on demographics, previous computer experience, and preferred training method. This information was used to identify variables that could potentially influence performance.

Constructivist Group Self-Reports

At the conclusion of training, soldiers in the treatment group also rated the effectiveness of the constructivist method as it compared with those to which they had been exposed previously. A five-point Likert scale was used to obtain the self-report ratings. No counterpart information was collected on the conventionally trained soldiers.

Workload Assessments

The NASA-Task Load Index (TLX), a self-report workload measurement tool (Hart, 1987), also was administered to soldiers assigned to both training groups. The TLX was administered after the initial PE, at the midpoint of the instructional period, and following the experimental PE just prior to the final exam. Results from the TLX assessments were used to (1) establish the perceived workload involved in training digital skills and (2) note any differences in workload as a function of training method.

RESULTS

Training Method

As shown in Figure 4 (left side), scores did not differ statistically for conventional and constructivist groups on the schoolhouse final exam. Regardless of the training method, soldiers mastered the established learning objectives. However, as shown in Figure 4 (right side) the group taught using constructivism performed significantly better on the performance-based PE ($F(1,43) = 11.59$, $p < .05$; eta squared = .21). The constructivist training method developed soldiers who were able to apply their digital training more successfully than soldiers trained using the conventional method.

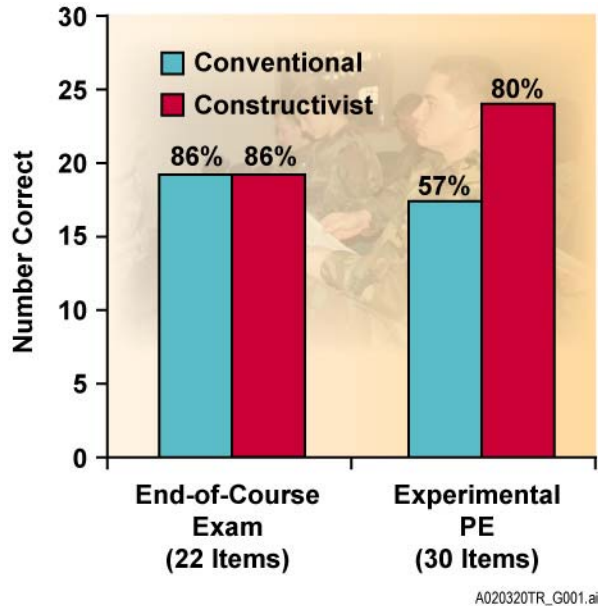

Figure 4. Course exam and experimental PE performance as a function of training method.

Soldier Background

No significant correlations were found between demographics (education, age, time in service, rank) and performance on either the schoolhouse exam or the experimental PE. However, results indicate that a majority of the soldiers entered the course with computer knowledge. For example, 64 percent owned their own computers and 91 percent described themselves as good with several software packages. Only one soldier reported never using a computer mouse.

Constructivist Group Self-Reports

Soldiers in the constructivist group expressed very positive reactions to the training experience, particularly the self-pacing aspect. Responses on the questionnaire indicated that these soldiers felt challenged and were highly motivated to learn (Figure 5). Teaming with other soldiers to frame and solve problems was seen as especially beneficial to learning. For example, one student stated, “It really helped when I had someone with my mind set teaching me. The instructors sometimes forget we haven't been thinking that much. It made me think harder on what I'm really doing and I see things in a different way.”

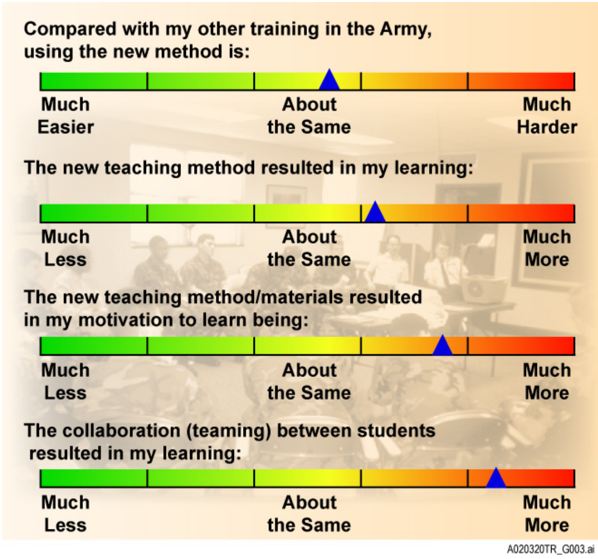

Figure 5. Soldiers' mean ratings of constructivist method of training.

Workload Assessments

Self-reports of workload after the first PE and at the midpoint of the training indicated no significant differences between the groups trained using the conventional or constructivist method. However, significant differences were found ($F(1, 42) = 8.47$; $p < .05$) following the final experimental PE that required soldiers to apply their training to an unfamiliar problem. Soldiers trained using the conventional method reported higher levels of mental demand, time stress, and effort than did the constructivist-trained group. Additionally, the group trained under the conventional method rated their performance lower than did the constructivist-trained group (Figure 6).

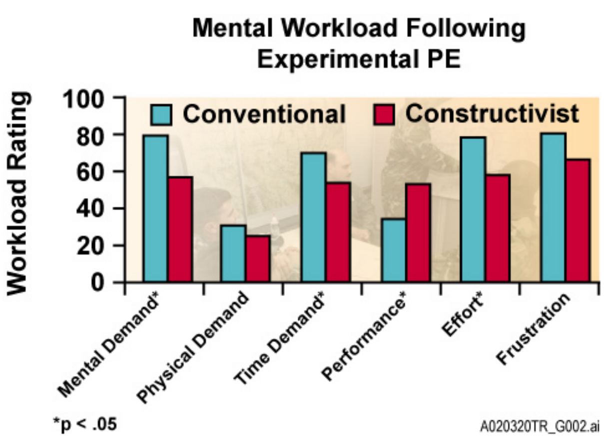

Figure 6. Perceived workload and performance following the experimental PE.

Performance on the experimental PE provided insight into soldier performance capabilities when they arrive at their unit. The experimental PE changed the map location, database, and mission. Similar changes can be expected in the unit. Table 3 shows the percentage of soldiers who reported workload levels of 90 or higher on the 100-point workload scale (0 = lowest workload rating, 100 = highest workload rating). NASA-TLX results suggest that soldiers taught by the conventional method may experience difficulty applying their knowledge and may require review and additional practice to transfer training from the classroom to the unit.

Table 3 summarizes NASA-TLX workload ratings for the two training groups. The results show clear differences in favor of the constructivist group with regard to soldiers reporting high workload on the scale. These results support long-standing concerns within the military that operator workload must be addressed early and continuously during the design of a system (Christ, Bulger, Hill, & Zaklad, 1990) to ensure that it is not excessive. As stated on p. 17 of MIL-STD-1472C "Design shall be such that operator workload, accuracy, time constraints, mental processing, and communication requirements do not exceed operator capabilities." The best technology can result in mission failure if it imposes too high a workload on the operator (Chatham & Braddock, 2000).

Table 3. Percentage of Soldiers Who Experienced High Workload (Rating ≥ 90)

TLX Workload	Conventional Method	Constructivist Method
Mental Demand	45	7
Physical Demand	13	0
Time Stress	30	7
Performance	32	0
Effort	39	7
Frustration	47	21

Of particular note is that soldiers trained using the constructivist method covered more material in less time than those taught using the conventional method, yet they did not perceive an increase in workload. This was accomplished by developing an environment that actively engaged the learner in acquiring the specified competencies.

DISCUSSION

Constructivist methods present complex and varied problems requiring soldiers to think more deeply about what they are doing and why they are doing it. Results of this study showed that the effects of constructivist techniques were positive for learning and successfully applying ASAS-RWS functionality within an MI environment. Equally responsible for the success of this was the high level of motivation demonstrated by soldiers as they performed tasks in new situations. Relatively inexperienced soldiers were cast into unfamiliar roles and required to provide data and information essential to successful execution of a combat mission. For example, one of the separate digital TLOs in Intelligence Preparation of the Battlefield is to resize the map screen to three different resolutions. If this is taught as an isolated piece of knowledge (e.g, select XXX from the menu bar, click YYY, choose 1:50,000), the skill may not be correctly applied in actual use or remembered. On the other hand, if the soldier is required to "adjust the map scale to best convey the massing enemy forces to your team NCOIC," the soldier must process and apply additional information in context. He may ask himself the following:

- "What map area needs to be depicted?"
- "What friendly or enemy graphics must be shown to convey the enemy situation in context?"
- "What decision(s) will be made or aspect(s) of the operation may be influenced by this information?"
- "Is sufficient detail provided to make the decision(s)? If not, what additional detail is required?"
- "What map scale most accurately conveys this information to my NCOIC, Team Chief, and/or Commander?"

This self-interrogation process serves to expand the soldier's comprehension and familiarity with both emerging MI analytical skills and ASAS-RWS user skills.

Trainers using the constructivist method "scaffold" or coach by listening, identifying weak links in understanding or skill, and asking leading questions to allow the soldier to define the problem or issue, clarify goals, and improve performance. Trainees explore and discover how to perform or find a solution with minimal direction. The trainer's role is to probe and question the soldier to amplify understanding, prompt more in-depth learning, and ensure that important skills and concepts are acquired and understood. For example, consider that intelligence reporting has created two situations indicating the massing of enemy armor on the battlefield. One situation is the actual massing of armor forces for offensive operations. The other situation is the result of duplicate reporting from multiple sources on a single unit. The trainer could ask the following questions to focus the soldier's learning:

- "I see some indications of armored formations close together. Is it unusual to have armor this close?"
- "What appear to be the enemy's intentions?"
- "What are the reporting sources?"
- "What are the time frames for these reports?"
- "Have you looked at organizations and command relationships for these units?"
- "Have you determined the identities and subordination of these units?"

By thoughtfully responding to these questions, soldiers exercise their analytical skills and solve the problem, identifying both duplicate reporting and massed forces. Just as important, these analytical skills are rehearsed and reinforced via the capabilities and functions of a new digital tool, the ASAS-RWS. Participation in "train as you fight" methods may have encouraged soldiers to deal with problems on their own. Therefore, they were more adept at dealing with the stresses of the experimental PE. Developing an environment that actively engages the learner in acquiring the specified competencies requires careful design of the instructional setting and support materials so that they represent the "real world" while presenting a unit of learning. Instructors must resist the temptation to administer simple exercises, and instead, must allow soldiers to make and resolve errors in response to the unexpected to promote knowledge retention and knowledge transfer. Soldiers will advance faster if learning begins with elements of the complexity and uncertainty they will encounter in the field. This approach contrasts somewhat with that of the "building block" (crawl, walk, run) learning method, which requires students to master basic skills before moving on to more advanced skills.

Army units know that working together can help solve problems. However, what we sometimes forget is that the more competent the individual soldier, the more he/she contributes to the solution. Conversely, students possessing low levels of skill, knowledge, or motivation can serve as "weak links" that cause the solution chain to break. Explaining and defending a position or action can be a powerful learning tool, particularly when acquiring new and complex knowledge. Peers quickly ask questions when they don't understand and, equally important, point out incorrect assumptions or actions. The constructivist method requires adopting this type of learning, which prepares the soldier to learn how to learn and to transfer individual proficiency to the unit.

CONCLUSIONS AND RECOMMENDATIONS

Recommendations stemming from study results are shown in Table 4.

Table 4. Constructivist Training Recommendations

- Present complex and varied problems that make soldiers think about what they are doing and why.
- Develop an environment that actively engages the learner in acquiring the specified competencies.
- Plan and execute problem solutions with other soldiers.
- Coach by listening, identifying weak links in comprehension, and asking questions that allow the soldier to clarify goals and improve performance.
- Encourage soldiers to think about why they are responding in a given way, to try new solution sets, to assess their effectiveness, and to share learning outcomes with their peers and the instructor.
- Set group goals and hold individual soldiers accountable for their own learning.
- Resources permitting, allow soldiers to move through the course at their own pace.

Results from this research demonstrated a method of training that produces soldiers able to think flexibly and adaptively: soldiers who transfer and apply learning to unfamiliar situations. Additional benefits include increased motivation, decreased workload, and enhanced collaboration in problem definition and problem solving. Soldiers are taught how to take responsibility for their own learning, a skill necessary for future soldiers to master ever-changing requirements and maintain mission readiness.

Findings from workload assessments suggest that novice operators experience high levels of workload even in a structured learning environment. All soldiers experienced higher levels of workload when asked to apply their learning to an unfamiliar situation, but MI trainees taught under the conventional training method reported significantly higher levels of mental demand, time pressure, and required effort as compared with those trained using constructivist methods.

Training practices in the military should change to accommodate new military doctrine calling for smaller, more agile forces that can dominate the enemy through information superiority. As command organizations are flattened to create connectivity between the commander and the unit, individuals at lower levels will assume higher levels of operational responsibility and authority for execution. Appropriate training techniques must be matched with the material to be mastered and the competencies required. Equally important, trainers, both in the schoolhouse and in the unit, must receive support to understand and implement these changing training methods. Understanding and applying constructivist training methods can enhance the learning process and augment the capabilities of the soldier of the future to successfully solve complex, unfamiliar problems. Defining and implementing the best training practices to develop these future warriors must be a priority.

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