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OBJECTIVELY DEFINING SCENARIO COMPLEXITY: TOWARDS AUTOMATED,  
ADAPTIVE SCENARIO-BASED TRAINING

by

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A dissertation submitted in partial fulfillment of the requirements  
for the degree of Doctor of Philosophy  
in the College of Education and Human Performance  
at the University of Central Florida  
Orlando, Florida

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## **ABSTRACT**

Effective Scenario-Based Training (SBT) is sequenced in an efficient trajectory from novice to mastery and is well-grounded in pedagogically sound instructional strategies and learning theory. Adaptive, automated SBT attempts to sequence scenarios according to the performance of the student and implement the sequence without human agency. The source of these scenarios may take the form of a matrix constructed by Instructional Systems Designers (ISD), software engineers or trainers. The domain being instructed may contain procedures or concepts that are easily differentiated thus allowing quick and accurate determination of difficulty. In this instance, the sequencing of the SBT is relatively simple. However, in complex, domain-integrated instructional environments accurate and efficient sequencing may be extremely difficult as ISD, software engineers and trainers, without an objective means to calculate a scenario's complexity must rely on subjectivity.

In the Military, where time, fiscal and manpower constraints may lead to ineffective, inefficient and, perhaps, negative training SBT is a growing alternative to live training due to the significant cost avoidance demonstrated by such systems as the United States Marine Corps' (USMC) Abrams Main Battle Tank (M1A1) Advanced Gunnery Training System (AGTS). Even as the practice of simulation training grows, leadership such as the Government Accountability Office asserts that little has been done to demonstrate simulator impact on trainee proficiency.

The M1A1 AGTS instructional sub system, the Improved Crew Training Program (ICTP), employs an automated matrix intended to increase Tank Commander (TC) and Gunner (GNR) team proficiency. This matrix is intended to guide the team along a trajectory of ever-

increasing scenario difficulty. However, as designed, the sequencing of the matrix is based on subjective evaluation of difficulty, not on empirical or objective calculations of complexity. Without effective, automated SBT that adapts to the performance of the trainee, gaps in combat readiness and fiscal responsibility could grow large.

In 2010, the author developed an algorithm intended to computationally define scenario complexity (Dunne, Schatz, Fiore, Martin & Nicholson, 2010) and conducted a proof of concept study to determine the algorithm's effectiveness (Dunne, Schatz, Fiore, Nicholson & Fowlkes, 2010). Based on results of that study, and follow-on analysis, revisions were made to that Scenario Complexity (SC) algorithm.

The purpose of this research was to examine the efficacy of the revised SC algorithm to enable Educators and Trainers, ISDs, and software engineers to objectively and computationally define SC. The research process included a period of instruction for Subject Matter Experts (SME) to receive instruction on how to identify the base variables that comprise SC. Using this knowledge SMEs then determined the values of the scenarios base variables. Once calculated, these values were ranked and compared to the ICTP matrix sequence.

Results indicate that the SMEs were very consistent in their ratings of the items across scenario base variables. Due to the highly proceduralized process underlying advanced gunnery skills, this high degree of agreement was expected. However, the significant lack of correlation to the matrix sequencing is alarming and while a recent study has shown the AGTS to increase TC and GNR team proficiency (PM TRASYS, 2014a), this research's findings suggests that redesign of the ICTP matrix is in order.

I dedicate this work to my mother, Alberta Virginia Dunn (née Hood)  
My sister, Lynda Jean Dunn  
They taught me more than they lived to see  
Nicole Follet-Dunn, my wife, who keeps me going  
My son, Alex, who gives the best full-body hugs  
And  
My father, Raymond Eugene Dunn (retired Navy), for whom words fail to describe my thanks  
and love

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This research was supported by USMC Capt. Samuel Oliver (now in the Reserves and doing fine). He was the Project Manager for the Combat Vehicle Training Systems (CVTS) program under Program Manager Training Systems (PM TRASYS), Marine Corps Systems Command. It was an honor and a humbling experience to be part of a team that directly and positively impacted Marine warfighter's preparedness, survivability and readiness.

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## LIST OF ACRONYMS/ABBREVIATIONS

AA	Adaptive Automation
AGTS	Advanced Gunnery Training System
AugCog	Augmented Cognition
BP	Battle Position
CAS	Close Air Support
CFF	Call For Fire
CCM	Cognitive Context Moderators
DoD	Department of Defense
DOTD	Directorate of Training and Doctrine
FORTTRAN	Formula Translating
G	Generalizability
GNR	Gunner
GTLF	Gate to Live Fire
HELIVAC	Helicopter Evacuation
IBM	International Business Machines
ICTP	Improved Crew Training Program
IO	Instructor Operator
IRB	Institutional Review Board
ISD	Instructional System Design
ISD	Instructional System Designer
KSA	Knowledge, Skills and Ability
LVC	Live, Virtual and Constructive
M1A1	Abrams Main Battle Tank
MEF	Marine Expeditionary Force
MOS	Military Operational Specialty
NETP	National Education Technology Plan
PC	Personal Computer
POI	Program of Instruction
SBT	Scenario-Based Training
SIO	Senior Instructor Operator
SC	Scenario Complexity
SCORM	Shared Content Object Reference Model
SME	Subject Matter Expert
SSgt	Staff Sergeant
T&R	Training & Readiness
TC	Tank Commander
TC	Task Complexity
TF	Task Framework
TSUH	Training System Utilization Handbook
USMC	United States Marine Corps

## CHAPTER ONE: INTRODUCTION

After almost 60 years of research in the area of training interventions, few empirically supported guidelines have emerged to direct the choice and implementation of effective, automated training interventions (Bolton, 2006). Today, the Instructor/Operator (IO) of a training simulation system using Scenario Based Training (SBT) is often heavily tasked and often cannot dedicate the cognitive resources necessary to effectively and efficiently sequence scenarios in a trajectory from novice to expert. Automated SBT matrices intended to mitigate this condition provide scenario sequencing that have limited, if any, objective or empirical foundation. That is, matrix sequencing is ultimately based on Instructional System Designer (ISD), software engineer, or IO subjective perception of difficulty. Therefore, it is not necessarily true that automated matrices sequence scenarios from novice to expert levels accurately, efficiently and effectively. To automate and, more importantly, adapt to the performance of the trainee software solutions must be in place to computationally define Scenario Complexity (SC) and prescribe the complexity level of the follow-on scenario. That is, an objective, computationally actionable value must be attributed to each scenario so that advancement or remediation along the trajectory can be grounded in sound instructional strategy and learning theory.

The purpose of this research was to examine the efficacy of the revised SC algorithm to enable Educators and Trainers, ISDs and software engineers to objectively and computationally define SC. The SC algorithm was revised to advance efforts in the design of SBT that adapts and automatically initializes, constructs, and sequences scenarios based on trainee performance.

Results of the author's proof of concept study (Dunne, Schatz, Fiore, Nicholson, et al., 2010) formed the basis of these revisions.

The first and second sections of this chapter present an overview of the major aspects of this research and a statement of its purpose. The third and fourth sections present the problem statement and definition of terms. The fifth section outlines major limitations while the sixth section outlines the study's major assumptions. The seventh and eighth sections discuss the justification, and conceptual framework of the research. The research questions are presented in the ninth section. The tenth section outlines the organization of the remainder of the dissertation.

### Overview

In efforts to computationally define SC the author developed an initial algorithm and conducted a pilot study to determine its potential. This SC algorithm included characteristics such as: Task Complexity (TC), Task Framework (TF) and Cognitive Context Moderators (CCM). These characteristic's values were derived from base variables such as number of sub-tasks and conflicting outcomes and enabled calculation of total SC. Two papers document these efforts and results: Dunne, Schatz, Fiore, Martin and Nicholson, (2010) and Dunne, Schatz, Fiore, Nicholson and Fowlkes (2010). Outcomes of those efforts resulted in the seminal SC algorithm and indicated promising results. Analysis of that proposed SC algorithm led to the revisions of the SC algorithm researched for this dissertation.

The Military has been at the forefront of SBT since the first flight simulator was adopted in 1934 (Link, 2009) and continues to incorporate simulation and associated instructional software into their Programs of Instruction (POI). According to United States Marine Corps (USMC), it is doctrine for a tank crew, defined by Directorate of Training and Doctrine

Maneuver Center of Excellence (DOTD, 2013), as a Vehicle Commander and Gunner (GNR), to successfully complete Gate-to-Live-Fire (GTLF) simulated scenarios provided by the M1A1 AGTS simulators prior to engaging in Live-Fire Qualification (USMC, 2009, 2010, 2011, 2012, 2013). To assist in meeting this requirement, the Improved Crew Training Program (ICTP), a matrix of automatically sequenced scenarios that shepherds trainees from novice to expert levels (Lockheed Martin, 2012), was embedded in the AGTS training software.

At the core of the ICTP matrix is the instructional strategy of “crawl, walk, run”. The “crawl, walk, run” approach creates training trajectories that require acquisition and maintenance of knowledge, skills, and abilities (KSA) at ever advancing levels, similar to the trajectories described by Clements and Battista, (1992) and Fuson, (1997). This is a standard instructional strategy in the US Army and USMC because the “crawl, walk, run” process is an effective method of training to standard for drills and individual and collective tasks (US Army, 1996) and is supported by learning theories described by Vygotsky (1972) and Krashen (1982). However, due to differing trainee schema inherent to mixed-rank or mixed-experience conditions, what is “run” to a Lance Corporal may be a “walk” to a Staff Sergeant (SSgt). Perception of a scenario’s difficulty is subjective, and is not computationally actionable. Therefore, if effective sequencing of SBT is to be ensured, a scenario’s level of difficulty must be determined apart from the trainee. The scenario itself must possess a value, an operational sum that can be objectively determined and computationally actionable.

The ICTP matrix is intended and designed to automatically sequence scenarios from novice to expert level scenarios. The matrix has a vital impact on the instruction of Abrams



Main Battle Tank (M1A1) gunnery in the AGTS. Due to these factors, and the downstream effects of AGTS training, it is important to ask: is the matrix sequencing, in fact, correct.

### Purpose of this Research

The purpose of this research was to examine the efficacy of the SC algorithm to enable Educators or Trainers, ISD and software engineers to objectively and computationally define SC. Part of this process included a period of instruction given to the participants, Subject Matter Experts (SME), in the identification of the characteristics that comprise the SC algorithm. Using this knowledge SMEs then determined the values of the SC base variables. These base variables, once calculated, determined the objective total SC values which were then ranked and compared to an existing matrix sequence derived from the ICTP embedded in the M1A1 tank Advanced Gunnery Training System (AGTS).

This research is intended to advance the field of SBT by indicating a method of designing SBT that adapts and automatically initializes, constructs, and sequences scenarios based on trainee performance. With the base variables, and characteristics of the revised SC algorithm this research uses the ICTP matrix as a filter through which the efficacy of the revised SC algorithm are evaluated.

### Statement of the Problem

As Bolton (2006) found eight years ago, still, after almost 60 years of research in the area of training interventions, few empirically supported guidelines have emerged to direct the choice and implementation of effective, automated training interventions. The IO of a training simulation system using SBT is often heavily tasked and often cannot dedicate the cognitive

resources necessary to effectively and efficiently sequence scenarios in a trajectory from novice to expert. Automated SBT matrices intended to mitigate this condition provide scenario sequencing that have limited, if any, objective or empirical foundation. That is, matrix sequencing is ultimately based on ISD, software engineer or IO subjective perceptions of difficulty. Therefore, it is not necessarily true that automated matrices sequence scenarios from novice to expert levels of complexity accurately, efficiently and effectively. To automate and, more importantly, adapt to the performance of the trainee software solutions must be in place to computationally define SC and prescribe the complexity level of the follow-on scenario. That is, an objective, computationally actionable value must be attributed to each scenario so that advancement or remediation along the trajectory can be grounded in sound instructional strategy and learning theory.

Dunne, Schatz, Fiore, Martin et al. (2010, p. 2) assert “it is crucial to objectively define and instantiate scenario complexity so the software can calibrate and assemble appropriate SBT episodes. Successful instantiation depends on creating an objective computational metric of the subjective notion of difficulty”.

Beyond the efforts of this author, a search of recent literature does not locate any such research towards developing an algorithm or intervention that addresses this need.

### Definition of Terms

Noam Chomsky (1973) said, “The interpretation and use of words involves a process of free creation.” However, there are terms contained within this dissertation that, to avoid misunderstanding, should not be left open for interpretation. A definition of terms is herein supplied to ground readers to the content with common interpretation and understanding.

*Adaptive Automation (AA):* Machine-centric agency whereby the behavior of the user triggers actions in the system that guides the learning process (Burgos, Tattersall & Koper, 2007), thus carrying out functions normally performed by a human agent (Parasuraman & Riley, 1997). Herein, when adaptivity is referred to it is in the context of a software solution that determines the sequence of SBT scenarios based on the performance of the trainee, relieving the human agent from this task.

*Base Variables:* These are the foundational eight variables, the first tier of values, used to calculate the values of the scenario's characteristics from where the total SC value is derived. They include number of: required acts, information cues, subtasks, interdependent tasks, task paths, task criteria, task conflicts and CCM or, more simply, distractors.

*Characteristic:* The characteristics of a scenario form the second tier of the SC algorithm; they determine the total SC value. These characteristics are: TC, TF and CCM.

*Cognitive Context Moderators:* CCM are external stimuli that affect the trainee by increasing cognitive load or reducing cognitive resources, or both, for the task, thus causing less complex tasks to appear more complex. They may be referred to as distractors, although that term is less descriptive. Note that CCM is also a base variable; the base variable CCM is modified to create the CCM characteristic.

*Component Complexity:* This sub-characteristic is comprised of two base variables; number of subtasks, or acts, and the number of information cues to be processed to perform those required subtasks or acts (Wood, 1986). When this sub-characteristic is modified by the Coordinative Complexity sub-characteristic the characteristic of TC is derived.

*Conflicting/Unknown Outcomes:* This base variable accounts for outcomes where achievement of one criterion can conflict with achieving another or the outcome of achievement is unknown. For example, conflicting outcomes may include the desire to drive and arrive at destination within a certain time (criterion) versus getting there without violating traffic laws (conflicting criterion).

*Coordinative Complexity:* This sub-characteristic accounts for the number of antecedent and/or interdependent relationships among the task elements (Wood, 1986). When this sub-characteristic is modified by the Component Complexity sub-characteristic the characteristic of TC is derived.

*Difficulty:* Difficulty is a subjective experience related to performance but does not necessarily correspond to performance levels or learning (Zook, Lee-Urban, Riedl, Holden, Sottolare, & Brawner, 2012). Difficulty is an intrinsic perception and, as such, cannot be the source of a computationally proceduralized sequence to deliver scenarios of appropriate performance levels.

*Evaluation Phase:* This term describes a distinct time period of the research design wherein the participants evaluated a group of ten scenarios. There are a total of three scenario evaluation phases.

*Information Cues:* A base variable of the Component Complexity sub-characteristic an information cue is a source of information that must be monitored for completion of the task/subtask. For example, the task of driving to a new restaurant includes the subtask of navigating; this subtask requires monitoring of landmarks and signs as well as any directional aid within the car.

*Interdependent Tasks:* This base variable accounts for the integration of subtasks and associated acts. For example, when driving the subtasks of steering and navigation are interdependent; these subtasks are integrated and involve synchronization of activities to achieve the common goal or objective (Baker, Day, & Salas, 2006). Together with sub-task they form the basis of the sub-characteristic of coordinative complexity.

*Required acts:* A component to the sub-characteristic of Component Complexity Wood (1986), defines a required act as a pattern of behavior with identifiable purpose or direction that is non-redundant with other acts and is necessary for the successful completion of the task.

*Scenario-Based Training:* The purposeful instantiation of simulated events to create desired psychological states (Martin, Schatz, Bowers, Hughes, Fowlkes, J. & Nicholson, 2009). SBT is typically a self-contained learning environment that addresses specific instructional objectives by employing characteristics of simulations or games, or both.

*Scenario Complexity (SC):* The objective value of a scenario that interacts with individual characteristics (e.g., trainee expertise) to yield an individual's perception of the scenario's difficulty (Lum, Fiore, Rosen, & Salas, 2008). Complexity, in this context, is the objective counterpart to subjective "difficulty" (Dunne, Schatz, Fiore, Martin, et al., 2010; Dunne, Schatz, Fiore, Nicholson, et al., 2010). SC total is attained by implementing the SC algorithm for calculation of the values of the scenario's characteristics, sub-characteristics and base variables (Dunne, Schatz, Fiore, Martin et al., 2010).

*Sub-task:* According to Dunne, Schatz, Fiore, Martin et al., (2010, p. 2) a sub-task is a component of Component Complexity and a "task that is prerequisite, antecedent, or otherwise

integral to the performance of the overarching task. A subtask has a clear duration, a desired outcome or objective, and associated measures of performance.”

*Task Complexity (TC):* Task complexity is operationalized and manipulated by increasing or decreasing the number of sub-characteristics present in the task itself and that task complexity is the sum of two sub-characteristics: 1) component complexity and 2) coordinative complexity (Wood, 1986).

*Task Criteria:* is defined as a measurement that must be satisfied in order to reach the desired objective. Task criteria, or outcomes, measure performance and are aligned to the training objective. Every task has at least one criteria or outcome. For example, in USMC M1A1 gunnery, two task criteria (measures of performance) are time to ID and target classification.

*Task Framework:* Task framework accounts for the relation between task paths and the criteria or outcomes associated with each, and it addresses which criteria or outcomes are possible in a given task (Campbell, 1991).

*Task Paths:* Defined as the number of possible ways to arrive at the desired objective. Having numerous ways to reach the desired objective decreases the complexity of a task unless, as is often the case, the presence of multiple correct paths is illusory or an efficiency criterion is embedded in the task (Campbell, 1991).

The figure below illustrates the eight base variables, the two sub-characteristics, the characteristics and their relationships to the total SC value.

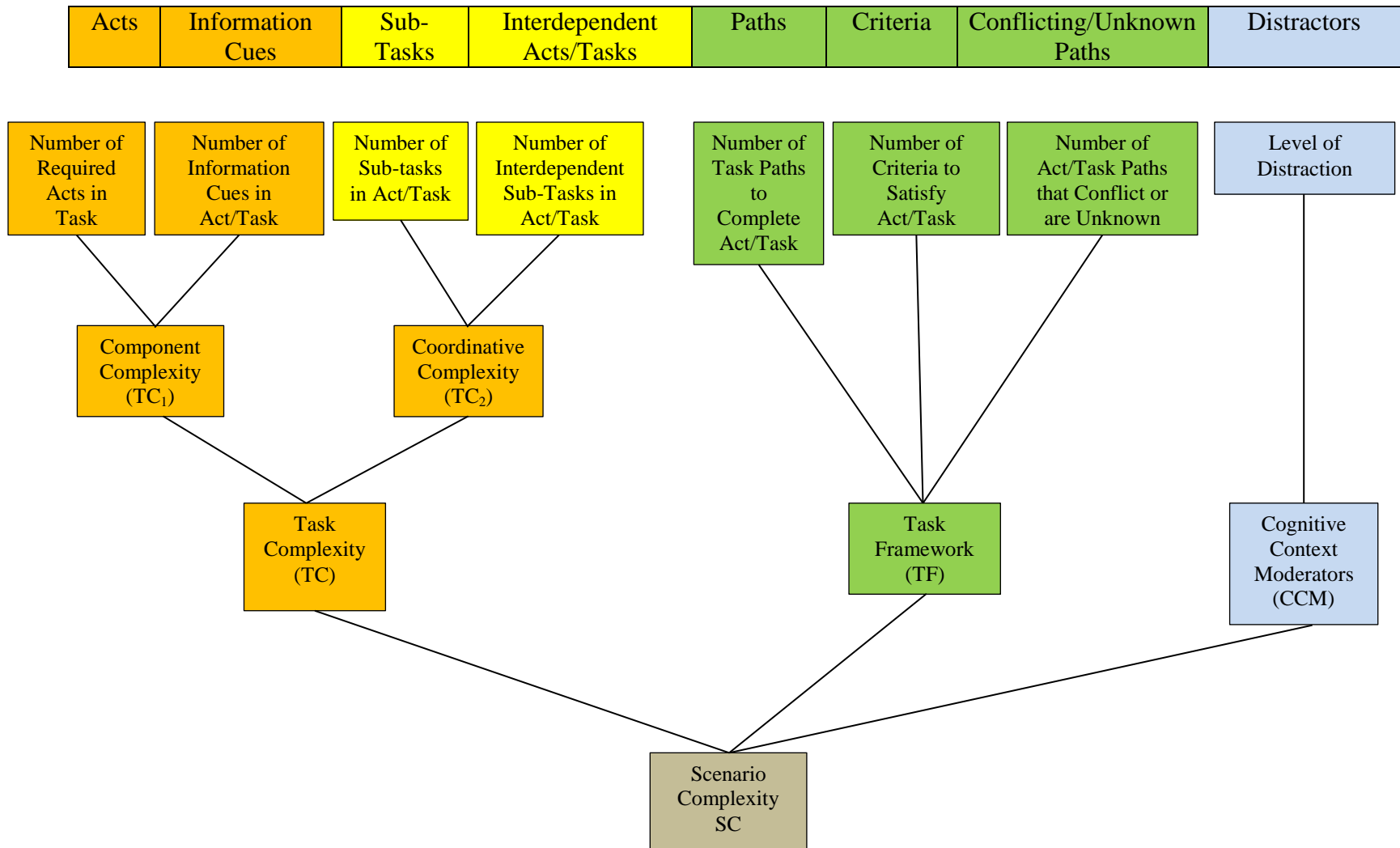


Figure 1: SC Characteristics and Variable Relationships

### Major Limitations of the Study

There were two major limitations of the study. One was a known limitation going into the collection of data while the other was uncovered during collection of data.

The first was the number of qualified participants available. The researcher recognized that due to the unique and specialized qualifications and skill sets necessary for SMEs of the M1A1 AGTS the population was small at the outset and, logistically, obtaining access to anything more than a handful of SMEs would be extremely difficult.

Within the USMC there are only 116 active duty and 86 reserve unit M1A1 crews. There is no Military Operational Specialty (MOS), or job position, for AGTS IO or Senior Instructor Operators (SIO). Without a dedicated MOS IOs and SIOs must be certified from this already unique population. Although the M1A1 AGTS is also employed by the US Army and the Saudi Arabian National Guard, USMC M1A1 combat procedures and training standards vary significantly. Nevertheless, including these Military branches there may still only be a total of 50 AGTS IOs and SIOs worldwide. Gathering 10% of this population in one place can be considered extraordinary. The researcher was very fortunate and humbled to have this rare opportunity and to be granted access to five AGTS SME available at 2<sup>nd</sup> Marine Expeditionary Force (MEF), 2<sup>nd</sup> Tanks Battalion based in Camp Lejeune, NC.

The effect of this small population is minimized due to the focus and statistical regime of this research. This small number of participants was not as threatening to validity or reliability of results as it would be if this were human subject research. Further explanation is provided in Chapter Three.



The second limitation became apparent during the data collection. The amount of time available for the instruction of the identification and familiarization of the base variables of the SC formula and collection of evaluation responses was extremely restricted and results suggest fatigue may have become a factor.

The participants were all active duty Marines fully tasked at the time of data collection. They participated in this study, and I was allowed access, with the condition that they return to their duties as quickly and with as little disruption to their base operations as possible. Therefore, where additional time would have been advantageous and may have mitigated the influence of fatigue; it was not a luxury afforded by the situation.

What affect this time constraint may have had on the responses of the participants is difficult to ascertain. However, it may be worth noting that time-stress is a normal part of their IO and SIO duties and certainly something that, as Marines with combat experience, they are acquainted.

### Assumptions

The majority of essential assumptions of this research were met. The primary assumption, access to M1A1 AGTS IOs and SIOs, was facilitated by the Battalion Master Gunner. In addition, the Marine Corps Combat Development Command Institutional Review Board (IRB) approved the research and the University of Central Florida IRB concurred.

As originally proposed, however, the assumption that 12 USMC participants would be made available was not met. Reason for this is mentioned in the limitations section above.

### Justification of Study

A review of literature finds that research and literature on sequencing of scenarios in SBT is nascent. At the time of the latest literature investigation, this researcher's efforts remain the only, objective, computational definition of scenario complexity forwarded (Dunne, Schatz, Fiore, Martin, et al., 2010; Dunne, Schatz, Fiore, Nicholson, et al., 2010).

The research conducted and the results attained from this study will assist in filling a vital gap. Implications of this research may guide investigations extending the SBT field and others such as serious gaming, mixed and computer-based instruction. Results of this research may lead to implementation of a theoretically grounded, automated instructional strategy that optimizes SBT scenario sequencing thus increasing efficiency and effectiveness as well as reducing or avoiding costs.

### Conceptual Framework

The conceptual framework for this study integrates two theoretical paradigms; Vygotsky's Zone of Proximal Development (1978) and Krashen's *i+1* Theory of Learning and Acquisition (1982). Both theories prescribe a progression wherein each succeeding task is more complex than those preceding. A more complex task involves more detail for some component characteristic or more total component skills than the preceding task (Merrill, 2007). The complexity of these tasks may affect the trainee's ability to build and maintain situation awareness if the complexity exceeds available working memory and storage processes (Jodlowski, 2008). Careful sequencing is necessary to avoid overloading and reducing training quality.

Two recent innovations, the Shareable Content Object Reference Model (SCORM) which was a result of the Advanced Distributed Learning initiative out of the DoD in 1997, and Augmented Cognition (AugCog), attempt to adapt sequencing of content or task delivery depending on performance and learner state. However, SCORM's level of remediation or advancement depends on the content of its POI "package" and is limited to the number of branches designed and developed by the ISD. AugCog depends upon bio-physiological input, sometimes gathered by distracting or invasive, or both, sensors. AugCog's purpose focusses on identifying work-load stress instances to indicate mitigating strategies, not knowledge acquisition.

Each of these attempts are iterations, in one form or another, of the Zone of Proximal Development (Vygotsky, 1978) and  $i+1$  (Krashen, 1982). The basis of the Zone of Proximal Development (ZPD) and  $i+1$  is the concept of increasing difficulty to optimize learning acquisition. ZPD represents a phase in development where a person is unable to perform a task alone but can eventually accomplish it with help from someone more experienced. After they accomplish that task they continue their scaffolding to higher levels of skills and concepts by the same method. ZPD describes the range of difficulty of tasks that are too hard for the learner to complete alone, but can be completed successfully with the appropriate assistance of someone more knowledgeable (Louis, 2009). Vygotsky's own translated definition describes the zone as "the distance between the actual development level as determined by independent problem solving and the level of potential development as determined through problem solving under guidance or in collaboration with more capable peers." (Vygotsky, 1978, p. 86).

From the SBT perspective, the sequencing of scenarios and their levels of complexity are similar to the tutor's ability to adjust levels of guidance and content to the tutee. Utilizing increasing complexity, adjusting levels to the ZPD of the trainee, guiding them along their trajectory to successful completion of SBT enables transfer of KSA to real-world situations. Eun, Knotek, & Heining-Boynton, (2008) suggest "children who have successfully progressed through the ZPD (i.e., reached their endpoint of proximal development) should be able to generalize skills they have acquired within the zone to other real-life situations..." (p. 142).

Krashen's  $i+1$  describes a learner's zone of current understanding or comprehension ( $i$ ) and the step above but not beyond understanding or comprehension ( $+1$ ). According to Krashen (1982), learned competence and acquired competence develop in very different ways. In his view, learning occurs through the formal study of rules, patterns, and conventions, a study which enables one to talk about and consciously apply the knowledge gained. The most valuable input for acquisition, however, is language that goes just a step beyond the structures which students have already acquired or, in Krashen's terminology,  $i + 1$ .

Krashen states, "the input [instructors] provide for children includes  $i + 1$ , but also includes many structures that have already been acquired, plus some that have not ( $i + 2$ ,  $i + 3$ , etc.) and that the child may not be ready for yet" (Krashen, 1982, p. 23).

These two theories' similarities lead to attempts to draw parallel conclusions (Evensen, 2007; Schinke-Llano, 1993) as well as arguments that any similarity is at best superficial (Dunn & Lantolf, 1998; Lantolf, 2008). Lantolf (2008) clarifies the issue by asserting that, "Krashen's  $i+1$  is a construct that relates to everyday learning, which should be replicated in the educational

setting, while Vygotsky's ZPD is much more closely connected to intentional educational development of the person (p. 217).”

### Research Questions

The purpose of this research is to examine the effectiveness of an algorithm intended to enable Educators or Trainers, ISDs and SMEs to objectively and computationally define SC. Part of this process includes the evaluation of an automated training matrix embedded within the instructional software of the M1A1 AGTS and by comparing its scenario sequences to those derived from the objective values determined by the SC algorithm.

For this study, the following research questions were asked:

Q<sub>1</sub>: How consistent were the SMEs ratings of the items?

Q<sub>2</sub>: How well do the SMEs rankings match to the ICTP sequences of the training matrix?

### Organization of the Remainder of the Dissertation

Situating this research in the continuum of instructional technology, where advanced technology and the affordances associated with it intersect with SBT, chapter two first presents a historiography of SBT. This is followed by reviews of the literature relating to SBT and SC and, where necessary, to peripheral areas. Special focus is given to the author's previous studies which developed the original SC algorithm and formed the foundation of this research. To address the conceptual framework, literature regarding Vygotsky's ZPD (1972) and Krashen's *i* +1 (1982) is also included. Chapter three describes the methodology, the materials and instruments used, procedure and, for clarification purposes, a narrative illustrating the data collection procedure. Special focus is again given to the analysis of the original algorithm and

the measures taken to develop the algorithm, or SC instruments which serve as the foundation of this research. Chapter four delivers the results of the study broken down by research question and SC base variables, sub-characteristics, characteristics and total SC. Chapter five discusses the findings, limitations, future directions and implications.

## CHAPTER TWO: LITERATURE REVIEW

The purpose of this research was to examine the efficacy of the Scenario Complexity (SC) algorithm to enable Educators or Trainers, Instructional System Designers (ISD) and software engineers to objectively and computationally define SC. Part of this process included a period of instruction given to the participants, Subject Matter Experts (SME), in the identification of the characteristics that comprise the SC algorithm. Using this knowledge SMEs then determined the values of the SC base variables. These base variables, once calculated, determined the objective total SC values which were then ranked and compared to an existing matrix sequence derived from the Improved Crew Training Program (ICTP) embedded in the Abrams Main Battle Tank (M1A1) Advanced Gunnery Training System (AGTS).

The primary goal of this review is to locate research literature that investigates operationalizing and defining SC in relation to Scenario-Based training (SBT). However, a preliminary search found that the only articles that deal specifically with the calculation of scenario complexity are by this author.

For a more robust and grounded literature review, it was necessary to widen the net and capture information from three secondary elements of this study. These secondary elements intersect with this dissertations purpose; literature that focused on SBT and Adaptive Automation (AA). To support the conceptual framework, articles regarding Vygotsky's Zone of Proximal Development (ZPD) and Krashen's  $i+1$  were also reviewed.

The first section of this review presents a historiography of simulation, technology and SBT along with innovations in learning theory in order to situate this study along the continuum these subjects bound. The second section describes the search methods and procedures used in

the determination of appropriate literature for review. The third section reviews SBT literature to more clearly define the field of study. The fourth section gives special focus to the original SC algorithm and describes the results from the pilot study. Section five reviews AA literature and focusses on the definition of the hierarchical categories, or types, of AA. Section six describes the two theories that are the foundations for this research's conceptual framework and at the heart of scenario sequencing. Finally, section seven ends chapter two by presenting the conclusions derived from the review of the germane literature.

### Historiography

For centuries, whether in the form of hypothetical syllogism, “if” situations posed by classical philosophers like Socrates and Plato in order to elicit “then” solutions from students, or in the form of battle scenarios played out with small models on broad tables by Emperor Napoleon and General Carl von Clausewitz, SBT and simulation have been a part of education and training.

Throughout the centuries technology has played a supporting role to learning theory and training demand, for learning theory and training cannot be separated from technology any more than technology can be separated from learning theory and training. Now, in the early years of the 21<sup>st</sup> century, the technological affordances which began in the early years of the 20<sup>th</sup> century have taken a leading role in the evolution of SBT and simulation.

At the end of the 19<sup>th</sup> century technology was limited to simple delivery devices (e.g., chalkboard, lectures). Instruction and training relied on repetition, drilling, and rote memorization. John Dewey, in 1891, described what we now refer to as automatization. In his words though, “In *learning* anything we voluntarily set ourselves to repeating an act so many



times that this act gradually separates itself from the background of ever-varying acts, and thus obtains a superior hold upon consciousness (p. 111).”

Half a century afterwards the right brothers flew, Henry Ford started the production line and World War I bred great and horrid innovations. Dewey, perhaps reflecting the larger disillusioned, societal reaction to the political, albeit no longer geographical, status quo, argued that the state of instruction was more, “a matter of routine in which the plans and programs were handed down (p. 5)” and called for “the need of a theory of experience (p. 3)” to take instruction further (Dewey, 1938). This call was answered by Pfeiffer and Jones (1975) with their experiential learning model based on the theory that people learn best by doing.

Concurrent to Dewey’s evolving views, British mathematician and computer scientist Alan Mathison Turing presented his paper, *On Computable Numbers* which introduced the concept of “algorithms” and the Turing machine proof, the basis of computability (Turing, 1936). In New York, an organ-makers son, Edward Link, mounted short wooden wings and a fuselage on a universal joint, used organ bellows for “pitch” “roll” and “yaw” and created the first flight simulator. This allowed pilots to learn by experience and practice knowledge and skills prior to actually taking off. He later equipped the cockpit with standard aircraft controls, radio aids, and gauges to help the pilot “fly blind” by using instruments (Link, 2009). Pilots who once trained by actually flying and watching the ground then used simulated flying scenarios (e.g., thick fog, night flight) and learned without the danger of being in flight.

By the mid-20<sup>th</sup> century Behaviorism lost its thrall over the firmament of Education and ceded reluctantly to Cognitivism, Piaget and, in Russia, to Vygotsky. “Game Theory,” the study of strategic decision making or, “...mathematical models of conflict and cooperation between

intelligent rational decision-makers" (Myerson, 1991, p. 1) extended SBT into fields like economy and diplomacy. Learning theorists and Military tacticians were joined by economists, psychologists, and scientists around the world who played out the ancient "if-then" game with the help of Universal Automatic Computer, International Business Machines (IBM), and Formula Translating (FORTRAN). Of course, by this time, technology had advanced into the home in the form of television; instructional programs coming with it when, in 1951, City Colleges of Chicago offered credit for taking televised courses.

In 1962, Gagne published, *The Acquisition of Knowledge* and distance learning, once dependent on mail correspondence and radio, became increasingly delivered by television. Computers the size of living rooms used magnetic reel-to-reel tape, bulbs, transistors, and punch-cards, and launched spacecraft that orbited the Earth first from the Baikonur Cosmodrome, Russia then from Cape Canaveral, Florida. By the end of the decade, the original internet, Advanced Research Projects Agency Network, or ARPAnet, went "online" and Man was on the moon thanks to the Apollo Guidance Computer and its 64k of memory.

In the 1970's Chess champion Bobby Fischer beat the Massachusetts Institute of Technology Greenblatt computer program in three consecutive games, and Lev Vygotsky's seminal work, *Mind in Society: The Development of Higher Psychological Processes*, was translated into English. In it, Vygotsky proposed the concept of the ZPD where learners performed within their range of competence while being assisted in realizing their potential levels of higher performance (Vygotsky, 1978). Gagne's foundational book, *Nine Events of Learning*, was published in 1974, and the Apple I and Commodore Pet computers entered homes in boxes and occupied only the corner of a room. Suddenly, Space Invaders were everywhere.

A common characteristic of such “video” games was that these games challenged players with levels of increasing difficulty maintaining motivation and a steady stream of quarters or tokens. Video or digital games, just like educational tools and resources were at the fingertip.

In the 1980’s, the effectiveness of SBT depended on the affordances of the computer and the proper implementation of appropriate instructional strategies (Barrows, 1985; Pfeiffer & Jones, 1975). In the relatively remote field of language acquisition, linguist Stephen Krashen (1982), proposed a learning theory similar to Vygotsky. Simply put, acquisition of knowledge is made possible by presentation of comprehensible input just a little above the learners current level; in other words: “*i+1*”. During this time computers became able to fully control the flow of the learning process (Tennyson, 1980) much like they did the flow of gaming.

During the 1990’s computers replaced typewriters on desks nationwide. 3.5 million “gamers” eagerly awaited the release of “Myst II: The Riven.” Chess champion Gary Kasparov played a best-of-three match against IBM’s Big Blue chess computer. He drew three times, won once and lost twice.

At the turn of the millennium, according to Ray Kurzweil (2001), technology was evolving exponentially, not linearly; in 2004, U.S. game sales were approximately \$7 billion. The average 8<sup>th</sup> grader spent about five hours a week playing video games (Oblinger, 2003; 2004). In the United States Marine Corp (USMC), SBT became a vital part of training programs such as the AGTS designed for the Abrams Main Battle Tank (M1A1).

In the later part of the first decade of the 21st century, Personal Computer (PC) games became employed for instructional purposes both in brick-and-mortar classrooms and online

environments. In the single month of December 2009, U.S. video game sales reached \$5.53 billion.

In 2013, within a single lifespan, technology has become pervasive. In the United States alone, in a single week, the top ten software-based games sold over 945,000 copies. External hard-drives contain over a terabyte ( $10^{12}$ ) of information.

Yet, games, training, and education remain predominantly rooted in the linear, non-adaptable sequence employed for centuries:

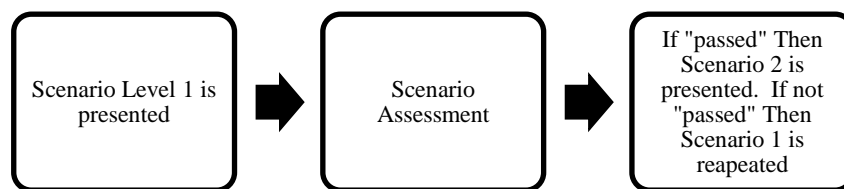


Figure 2: Traditional Linear Sequencing

### Search Methods and Procedures

The primary goal of this review was to locate research literature that investigates operationalizing and defining SC in relation to SBT. However, a preliminary search found that the only articles that deal specifically with the calculation of SC are by this author.

For a more robust and grounded literature review, it was necessary to widen the net and capture information from three secondary elements of this study. These secondary elements intersect with this review's purpose, therefore, literature that focused on SBT, AA, Vygotsky's ZPD and Krashen's  $i+1$  are reviewed herein.

There were five primary sources for literature; 1) the ERIC-EBSCOhost electronic database battery (from 1966 to August, 2014) including; ERIC, MAS Ultra - School Edition, Middle Search Plus, Primary Search, PsycINFO, PsycARTICLES, and Academic Search

Premier, 2) dissertation databases, 3) reference sections from articles chosen, 4) unclassified materials and documents acquired through employment position and work responsibilities and 5) personal collection of articles, books, conference materials and journals amassed during eleven years of study.

These online searches were conducted utilizing “peer review” and “full-text” as limiters where practicable. Where no explicit delineation between simulation and traditional environments was made in the abstract, description, or body of the study, it was assumed the study’s focus to be traditional, classroom environment. Additional searches were made to locate studies examining AA in combination with the other search terms such as SBT and ZPD.

A search of the ProQuest Doctoral Dissertation database, with search terms: “Scenario Based Training” and limited to appearance in the Abstract resulted in a total of 70 studies conducted in the last 10 years. Further exclusion factors reduced the number of relevant works to six. A search of the Institute of Electrical and Electronics Engineers XPlore database, with search terms: “Scenario Based Training”, limited to appearance in the Abstract, and key word: “adaptive” resulted in a total of 152 studies conducted in the last 25 years. Further exclusion factors reduced the number of relevant works to four. A search of the Computer and Information Systems Abstracts database, with search terms: “Scenario Based Training”, limited to appearance in the Abstract, and key word: “adaptive” resulted in only 4 studies conducted in the last 10 years. A search of the Applied Science and Technology database, with search terms: “Scenario Based Training”, limited to appearance in the Abstract, and key word: “adaptive” resulted in only 1 study conducted in the last 25 years but did not meet inclusion criteria. Further exclusion factors reduced the number of relevant works to six. EBSCOHost database search of

last 5 years, with same search parameters found no results. It was established, that a review of literature revealed a significant gap at the intersection of SBT + automated + adaptive + complexity.

Research in the areas of learning disabilities, teacher education, career development, sports, medical or counseling sciences, automated testing, or action research were eliminated from the search because they are not germane to the scope of this research or the study population was not appropriate, or both.

Literature inclusion criteria focused on two main areas: (1) studies with elements of the research topic and, due to limited number of such studies, (2) studies which address broader, foundational elements of the research topic.

### Scenario-Based Training

SBT is a whole task method (Reigeluth, 1999), that emphasizes performance and learning by doing. It employs real-world problems as the basis of learning and, as Kindley (2002) states, simulation makes learning by doing possible because it focuses on the learner's performance outcomes in a context that mirrors the real work environment.

For the warfighter the real work environment is the battlefield. "Train as you will fight," is one of the fundamental principles upon which Marine Corps training is based (USMC, 1996). SBT is an ideal vehicle for training within the USMC as SBT includes real-world problems like the pressures and "fog of war" as much as possible. At a time when avoidance of cost and the need for realism drive use of SBT (Aldrich, 2004) SBT, with its potential to present complex, authentic real-world tasks, lends itself to the type of task-centered instructional requirements (Merrill, 2007) the Military employs. Sequencing and tailoring SBT to the trainee's learning

needs may lead to more efficient and effective training. However, when humans are the originators of scenario sequencing, bottlenecks are created in the training process (Zook et al., 2012).

SBT enables realistic settings that improve the learning experience and enables demonstration of the desired knowledge and skills (Herrington & Oliver, 2000). By training in an environment similar to the real one, trainees learn how to apply skills from the very beginning in the proper context (Kenny & Pahl, 2009). Nardi (1997) states skills and knowledge are best acquired within realistic contexts that allow learners to participate in knowledge construction and skills training.

According to Aldrich (2004) a successful SBT relies on four ingredients, 1) authentic, relevant scenarios, 2) pressure situations that tap user emotions and force them to act, 3) a sense of unrestricted options and, 4) replayability. This is supported by Zook et al. (2012) who also list replayability, but add tailoring and ease of reconfiguration as desirable capabilities within SBT.

SBT relies on many principles of experiential learning in order to ensure problem-solving experiences are situated and anchored in real-world situations (Iverson & Colky, 2004). The situated learning that takes place eliminates the separation between learning and practical application (Choi & Hannafin, 1995).

A central concept to this study is supported by Zook et al., (2012) who point out that like serious games, SBT involves a progression of skill-based activities of increasing complexity structured through narrative or scenarios. Conversely, if skill-based activities do not progress

along a path of increasing complexity within the SBT then the training delivered will not progress beyond Knowledge Skills and Abilities (KSA) acquired by the act of repetition.

However, even with the best of intentions and designs SBT simulators present their own problems and limitations. Many simulators require experienced and skilled operators for the simulators to realize their full potential (Good, 2003; Bremner, Aduddell, Bennett, & Van Geest, 2006; Parker & Myrick, 2009). In the USMC, due to rotation, operations tempo and absence of a designated Military Operational Specialty (MOS) for the Instructor Operator (IO) or Senior Instructor Operator (SIO) of simulated training systems, experienced, trained instructors are in constant turnover. Consequently, expensive equipment with notable training affordances beyond its intended purpose is often under-utilized (PM TRASYS, 2014b). In addition, access may be limited when training efficiency and effectiveness is a vital consideration when only small numbers of students can use simulation equipment at one time (Smith, Gillham, McCutcheon, & Ziaian, 2011).

### Scenario Complexity

In the USMC Combat Vehicle Training System (CVTS) program, SBT scenarios can be sequenced manually by an IO or SIO based on training objectives, a description of the scenario, the trainees' level of experience, and operations requirements. Scenarios are also sequenced automatically through software.

During the course of instruction, the IO may determine it necessary to take scenarios that, due to time constraints or trainee performance, may reduce training efficiency or limit effectiveness, and tailor them or create new scenarios to fulfill training objectives. This itself is a time-consuming effort and depends on subjective experience and evaluation. Ullrich and Meles



(2010) investigated recent attempts to develop courseware that would aid in the generation and sequencing of content. Although their generator assembles a sequence of resources to support a student in achieving learning goals, it incorporates only basic pedagogy; has no notion of scenarios, and only a “book” of exercises from which to choose. That is, there is no automation or adaptation of the scenario or, to borrow a term from Kindley (2002) there is no *scenariation*, or software developed for the generation of tree-structured learning scenarios.

Although efforts to sequence scenarios have resulted in some promising products (e.g., Lockheed Martin’s Improved Crew Training Program [ICTP]) these products do not provide computational values of complexity to their scenarios. Therefore, software cannot sequence content based on performance with reliability or address trainee’s ZPD as there is no objective, range or baseline from which to take act. That is, just as in the case of Shared Content Object Reference Model (SCORM), such matrices are comprised of pre-produced scenarios which have been constructed by the operators and do not offer empirically reliable or valid performance-based sequencing.

Figure 3 shows the ICTP matrix that automatically shepherds the AGTS trainees from the lower left to the upper right in a trajectory of increasing difficulty (Lockheed Martin Corp., 2012).

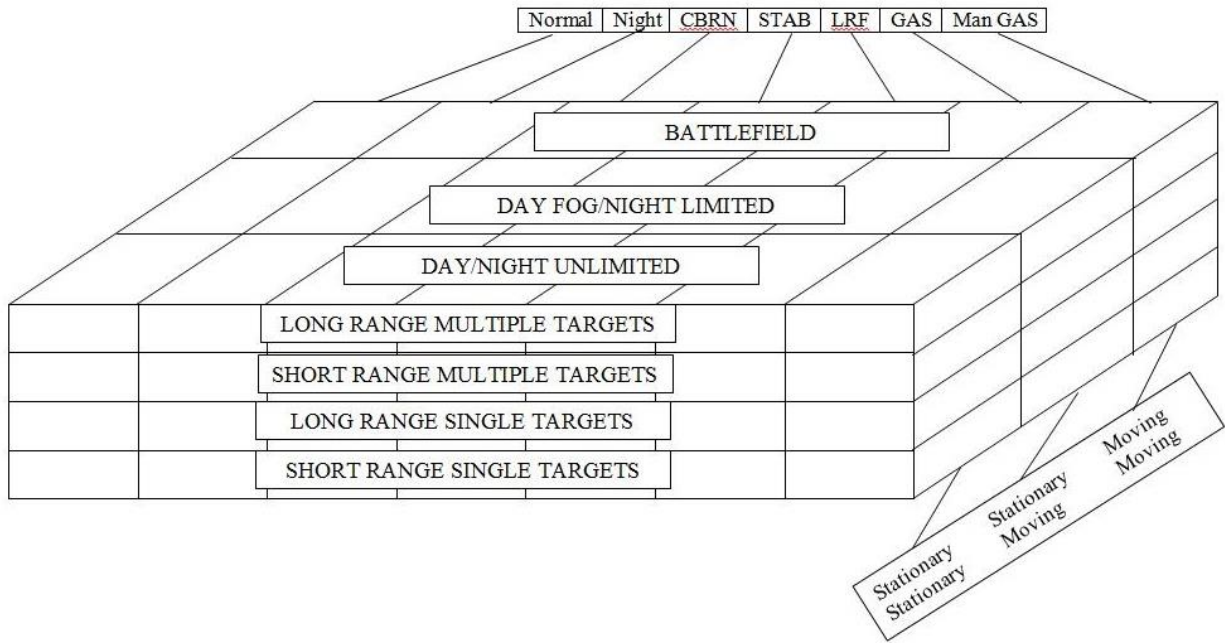


Figure 3: ICTP Matrix

### Task Complexity (TC)

A review of the literature finds several accepted definitions of TC (Kohn & Schooler, 1978; Wood, 1986; Frese, 1989; see Campbell, 1988 for a review). However, Dunne, Schatz, Fiore, Martin et al. (2010) and Dunne, Schatz, Fiore, Nicholson et al. (2010) use Wood's 1986 definition of TC. Wood asserts TC is operationalized and manipulated by increasing or decreasing the number of sub-characteristics present in the task itself and that TC is the sum of two sub-characteristics: 1) component complexity and 2) coordinative complexity.

*Component complexity.* This sub-characteristic is derived from three base variables: number of subtasks, required acts, and information cues. Shown in Figure 4 these base variables describe requirements of the task (e.g., engage and destroy two stationary targets) in a hierarchical fashion, with the primary task listed at the top, (optionally) broken into  $n$  subtasks, each of which may have  $n$  required acts and  $n$  number of information cues associated with them.

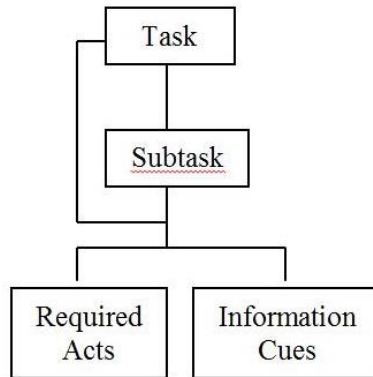


Figure 4: Task Complexity Hierarchy

### Task Framework (TF)

The second characteristic of SC, TF, expresses whether a task is well- or ill-defined by determining the number of task paths and task outcomes. TF accounts for the relation between task paths and the outcome associated with each, and addresses which outcomes are possible in a given task (Campbell, 1991). Campbell (1998) proposes four defining characteristics of task framework:

1. The presence of multiple potential ways (i.e., paths) to arrive at a desired end-state.
2. The presence of multiple desired outcomes (i.e., end-states) to be attained.
3. The presence of conflicting interdependence among paths to multiple outcomes.
4. The presence of uncertain or probabilistic links among paths and outcomes.

*Task path* is defined as the number of possible ways to arrive at the desired objective. Having numerous ways to reach the desired objective decreases the complexity of a task unless, as is often the case, the presence of multiple correct paths is illusory or an efficiency criterion is embedded in the task. *Task outcome* is defined as a criterion that must be satisfied in order to reach the desired objective; again, to use the targeting example, the

objective may require that the Gunner (GNR) identify target, choose ammunition and fire within a certain time frame *and* successfully overcome the target. *Conflicting outcomes* are those where successful achievement of one criterion can conflict with achieving another. For example: to arrive quickly at a Battle Position (BP) without intruding on infantry Area of Operations may require taking a long, less efficient route to the BP which is necessary to avoid interruption of friendly activity. *Uncertain linkages* accounts for increase in cognitive processing as a result of ambiguity, which increases the task's complexity.

### Cognitive Context Moderators (CCM)

As Dunne, Schatz, Fiore, Martin, et al. (2010) point out, Wood accounts well for observable, procedural, skill and rule-based human performance but ignores unobservable, cognitive task variables. Scenarios employed in SBT are often dynamic in nature such as flying an airplane, driving a vehicle automobile, or targeting and firing from a moving platform. In support, Reder and Schunn (1999) state that dynamic scenarios present a considerable cognitive load when compared to static tasks. The complexity of these tasks likely affects trainee ability to build and maintain situation awareness if the complexity exceeds available working memory processing and storage resources (Jodlowski, 2008). To support SBT, an environment where all domains of knowledge can be presented, it was proposed that cognitive tasks be accounted for in the formula.

Cognitive tasks are operationalized by referencing the cognitive task analysis body of literature. This field suggests that cognitive task analyses yield information about the unobservable thought processes that underlie observable task performance (e.g., Schraagen, Chipman, & Shute, 2000). Further, researchers already attempt to articulate the component parts

of cognitive tasks. For instance, Campbell (1991) offers articulated details for how to conceptualize decision, judgment, problem, and fuzzy tasks. Researchers such as Skehan and Foster (2001) as well as Robinson (2003) propose the manipulation of a series of cognitive task design factors to achieve different levels of task complexity, this supports the inclusion of the CCM variable in the SC formula. These factors inform two cognitive models of task complexity: Skehan and Foster's Limited Attentional Capacity Model (2001), and Robinson's Cognition Hypothesis (2003).

Considering this, a moderating characteristic based upon the degree of stress and distraction present in the scenario Dunne, Schatz, Fiore, Martin, et al. (2010) was added to the SC formula. CCM is defined as external stimuli that affect the trainee by increasing cognitive load or reducing cognitive resources for the task, or both, thus causing less complex tasks to appear more complex. For example, driving in ideal conditions is a less complex task than driving in fog or at night. For the purpose of this study values were derived from three conditions: no distraction, very high distraction, and somewhere in between. Thus values from zero to three were assigned from least to most distracting.

Dunne, Schatz, Fiore, Martin, et al. (2010) noted that care must be taken to discern the difference between external stimuli and subtasks. Driving an M1A1 is moderated by unreliable terrain, but communicating with the TC through the Combat Vehicle Communications device is a subtask and not a cognitive context moderator unless, as previously mentioned, the communication is unnecessary to the performance of the task or superfluous.

## Study Results

This study involved a single group ( $N=24$ ) comprised of undergraduate students recruited from a large southeastern university. Each participant completed four surveys that asked them to indicate their subjective perception of the complexity levels of various scenarios. These scenarios' complexity levels were calculated *a priori* using the SC formula.

The hypothesis was that the SC calculation would be similar to the results produced by the participants. In other words, it was expected that the formula yielded relatively comparable results, regardless of who assessed the scenarios. An independent, one-sample *t*-test was conducted to evaluate whether means were significantly different from the *a priori* test values.

Z-scores were derived to ascertain the degrees of agreement among participants' values. Z-scores between -1.249 and 1.249 indicated relative agreement as to a situation's difficulty. Z-scores  $< -1.25$  or  $> 1.25$  represented significant disagreement.

Two salient conclusions were drawn from the results of this study. First, Z-scores indicated significant disagreement at spectrum extremes; low and high complexity scenarios had a wider range of responses than did the middle-ground values. This suggested that there was a wide degree of disagreement when it comes to the simplest and most complex situations. There is, however, a significant level of agreement relating to middle-ground scenarios.

How these base variables, sub-characteristics and characteristics were modified and how the total SC formula was revised by this author is discussed in Chapter Three.

## Adaptive Automation

Adaptive automation refers to technology that can change its mode of operation dynamically. From the ISD perspective the determination of agency is not codified during the

design or development phases for adaptive systems processes. Human and machine agents of the system are dynamic during the operation of the system (Parasuraman, 2003). Some forms of automation allow dynamic changes in control function allocations between a machine and human operator based on conditions of the integrated human-machine system (Scerbo, Freeman, & Mikulka, 2003). Other systems perform adaptations during the training based upon trainee performance (Snow, 1992). Many intelligent tutoring systems use this approach exclusively (Ong & Ramachandran, 2005).

Proceduralizing the SC algorithm within the sequencing engine would allow automation to occur on three levels; the IO or SIO initiates changes between automated and manual modes or functionality (i.e., an adaptable system); the IO or SIO and the system initiate changes (i.e., an adaptive system) (Scerbo et al., 2003) or only the system initiates changes (i.e., an automated adaptive system).

Intelligent and adaptive computer-based tutoring has been pursued for almost 50 years (Hartley, 1973; Kinshuk, Patel, & Scott, 2001); Grabinger (1996) notes that we have had the technology to implement intelligent and adaptive systems as practical solutions for some time. Scerbo (1996) agrees that adaptive technology represents the next step in the evolution of automation and, according to Kenny (2006) SBT can sustain an interactive learning and training environment with an automated, adaptive tutoring system at the core. Adaptivity is not restricted to delivery of content as pointed out by the Kenny & Pahl (2009) article that also proposes adaptive feedback within an intelligent and adaptive tutoring system. This last suggestion however may have limited appeal to Military instructors.

Melis & Ullrich (2003) suggest that training in a realistic setting, such as found in high-fidelity SBT, needs to be combined with an automated tutor that provides immediate feedback and adaptive guidance. Although detailed feedback is traditionally the province of the human IO, Parasuraman & Sheridan (2000) state that computer hardware and software make it possible for the computer to carry out functions the IO would normally perform. Automation can objectively and efficiently carry out what is typically a subjective and time-consuming task. This degree of automation, however, does not necessarily eliminate the human role in the automation of a system (Parasuraman & Riley, 1997).

Burgos et al. (2007) proposes three types of automation: Interface based, learning flow based, and content based. The most directly applicable to this research is the latter two. In the learning flow based type, the system dynamically adapts to sequence the contents of the course in different ways every time the exercise is run (Burgos et al., 2007). In the content based type, resources and activities dynamically change their content based on adaptive presentation (Brusilovsky & Miller, 2001; De Bra, Aroyo, & Cristea, 2004).

Levels of automation can differ in type and human-system integration, from organizing information sources to suggesting decision options or even carrying out the necessary actions (Parasuraman & Sheridan, 2000). Table 1 shows a 10-level hierarchy that represents increased autonomy of computer over human action (Sheridan, 1987; Sheridan & Verplank, 1978; Wickens, Mavor, McGee, & United States National Research Council, 1997).



Table 1: 10-Level Automation Hierarchy

High	10. The computer decides everything, acts autonomously and ignores the human.
	9. The computer informs the human only if it decides.
	8. The computer informs the human only if asked.
	7. The computer executes automatically, then informs the human.
	6. The computer allows the human a restricted time to vet before automatic execution.
	5. The computer executes the suggestion if the human approves.
	4. The computer suggests one alternative.
	3. The computer narrows the selection down to a few.
	2. The computer offers a complete set of decision/action alternatives.
Low	1. The computer offers no assistance: human agent makes all decisions and actions.

#### Zone of Proximal Development and Krashens $i+1$

Merrill’s “pebble-in-the-pond” theory requires a good progression wherein each succeeding task is more complex than those preceding (Merrill, 2007). A more complex task involves more detail for some component characteristic or more total component skills than the preceding task. However, the complexity of these tasks likely affects trainee ability to build and maintain situation awareness if the complexity exceeds available working memory processing and storage resources (Jodlowski, 2008). Careful sequencing is necessary to avoid overloading and reducing training quality.

Two recent innovations, SCORM, and Augmented Cognition (AugCog), attempt to adapt sequencing of content or task delivery depending on performance and learner state. However, SCORM’s level of remediation or advancement depends on the content of its Program of Instruction (POI) “package” and is limited to the number of branches designed and developed by the ISD. AugCog depends upon bio-physiological input, sometimes gathered by distracting or invasive, or both, sensors. AugCog’s purpose focusses on identifying work-load stress instances to indicate mitigating strategies, not knowledge acquisition.

Wang et al., (2009) propose an adaptive system based on students' profiles to discover the most appropriate learning sequences for particular teaching content. As with most efforts to use adaptive instruction by calibrating entry level to pre-existing lesson sequencing, the presentation of instruction remains static and linear –the same conditions which these efforts are ostensibly attempting to avoid. While they attempt to address the problem of adhering to a fixed learning sequence in the traditional setting they merely substitute one fixed learning sequence with another.

Each of these prescriptions (Merrill, 2007; Wang, 2009) and efforts (SCORM, AugCog) are the latest iteration in the education and instructional fields to use the concepts, in one form or another, of the Zone of Proximal Development (Vygotsky, 1978) and  $i+1$  (Krashen, 1982) to optimize learner performance.

The basis of the ZPD and  $i+1$  is the concept of increasing difficulty to optimize learning acquisition. ZPD represents a phase in development where a person is unable to perform a task alone but can eventually accomplish it with help from someone more experienced. After they accomplish that task they continue their scaffolding to higher levels of skills and concepts by the same method. Krashen's  $i+1$  describes a learner's zone of current understanding or comprehension ( $i$ ) and the step above but not beyond understanding or comprehension ( $+1$ ).

ZPD describes the range of difficulty of tasks that are too hard for the learner to complete alone, but can be completed successfully with the appropriate assistance of someone more knowledgeable (Louis, 2009). Vygotsky's own translated definition describes the zone as "the distance between the actual development level as determined by independent problem solving

and the level of potential development as determined through problem solving under guidance or in collaboration with more capable peers.” (Vygotsky, 1978 p. 86).

In the case of training or tutoring, Wood, Bruner, & Ross, (1976) explore the role of the tutor in guiding the tutee through their ZPD. The qualities of the tutor are crucial in guiding the development of the tutee (Wood et al., 1976; Chak, 2001) The most important quality is the tutor’s ability to adjust level of guidance to the level of tutee’s functioning. It is easy to infer that support beyond the child’s comprehension level, or redundant does little to motivate development (Eun et al., 2008).

From the SBT perspective, the sequencing of scenarios and their levels of complexity are similar to the tutor’s ability to adjust levels of guidance and content to the tutee. Utilizing increasing complexity, adjusting levels to the ZPD of the trainee, guiding them along their trajectory to successful completion of SBT enables transfer of KSA to real-world situations. Eun et al., (2008) suggests “children who have successfully progressed through the ZPD should be able to generalize skills they have acquired within the zone to other real-life situations... (p. 142)” This last point is vital to warfighters where real-life situations demand lethality and survivability.

According to Krashen (1982), learned competence and acquired competence develop in very different ways. In his view, learning occurs through the formal study of rules, patterns, and conventions, a study which enables one to talk about and consciously apply the knowledge gained. The most valuable input for acquisition, however, is language that goes just a step beyond the structures which students have already acquired or, in Krashen's terminology,  $i + 1$ .

Krashen states, “the input they [caretakers] provide for children includes  $i + 1$ , but also includes many structures that have already been acquired, plus some that have not ( $i + 2$ ,  $i + 3$ , etc.) and that the child may not be ready for yet” (Krashen, 1982, p. 23).

These two theories’ similarities lead to attempts to draw parallel conclusions (Evensen, 2007; Schinke-Llano, 1993) as well as arguments that any similarity is at best superficial (Dunn & Lantolf, 1998; Lantolf, 2008). Lantolf (2008) clarifies the issue by asserting that, “Krashen's  $i+1$  is a construct that relates to everyday learning, which should be replicated in the educational setting, while Vygotsky's ZPD is much more closely connected to intentional educational development of the person.” This author asserts that in SBT, where experiential learning forms the basis and intentional educational development the objective, Lantolf’s attempt to differentiate dissolves. That is, if one accepts Lantolf’s description, then in SBT,  $i+1$  and ZPD encompass and fulfill the same intentions. A reconceptualization of these two concepts, at least in their application to SBT, is in order.

In any case, for these zones to be operationalized they must be computationally defined and it is to this end, and within these conceptual frameworks that the SC algorithm is herein researched.

### Review Conclusions

As result of this literature review it was established, that a significant gap at the intersection of SBT + automated + adaptive + complexity exists. In absence of adequate previous research on the proposed topic it can be concluded that this research and study is innovative and unique. While contributory literature in the areas of SBT, adaptive automation and, of course, foundational theoretical research such as Vygotsky’s and Krashen’s are readily available, efforts

of this study's author notwithstanding there is no locatable material regarding efforts to computationally define SC.

Literature pertaining to adaptive instruction presents a venue of robust research topics in education and training, but it lacks adequate representation of research relating to automation of SBT. Research that involves automating and adapting SBT environments also lags.

Where appropriate, application of literature findings to this research was forwarded. For example, according to Aldrich (2004) a successful SBT relies on four ingredients, 1) authentic, relevant scenarios, 2) pressure situations that tap user emotions and force them to act, 3) a sense of unrestricted options and, 4) replayability. This is supported by Zook et al., (2012) who also list replayability, but add tailoring and ease of reconfiguration as desirable capabilities within SBT. Implementation of the SC algorithm will fulfill these requirements for successful SBT.

Furthermore, software solutions that allow the IO or SIO and the system to initiate changes (i.e., an adaptive system) (Scerbo et al., 2003) or only the system to initiate changes (i.e., an automated adaptive system) can be implemented with the SC algorithm.

In the final analysis not only is there a vital gap which this research addresses, but the findings of this research may extend and fulfill the needs identified by the review of salient literature.

## CHAPTER THREE: METHODOLOGY

This chapter describes the procedures, participant demographics, research design, instrumentation and materials, with a special focus on the construction of the revised SC algorithm, and describes the statistical regime. For clarity, this chapter also includes a “notional narrative” that illustrates what may be considered an intricate data collection procedure, from start to finish. This chapter includes the following sections: 1) introduction; 2) participants; 3) materials and instrumentation; 4) ethical considerations; 5) procedure; 6) notional narrative and 7) statistical analysis.

### Introduction

The purpose of this research was to examine the efficacy of the Scenario Complexity (SC) algorithm to enable Educators or Trainers, Instructional System Designers (ISD) and software engineers to objectively and computationally define SC. Part of this process included a period of instruction given to the participants, Subject Matter Experts (SME), in the identification of the base variables that comprise the SC algorithm. Using this knowledge SMEs then determined the values of those SC base variables. These base variables, once calculated, determined the objective total SC values which were then ranked and compared to an existing matrix sequence derived from the Improved Crew Training Program (ICTP) embedded in the Abrams Main Battle Tank (M1A1) Advanced Gunnery Training System (AGTS).

This research is intended to advance the field of Scenario Based Training (SBT) by indicating a method of designing SBT that adapts and automatically initializes, constructs, and sequences scenarios based on trainee performance. With the base variables, and characteristics

of the revised SC algorithm this research uses the ICTP matrix as a filter through which the efficacy of the revised SC algorithm is evaluated.

For this study, the following research questions were asked:

Q<sub>1</sub>: How consistent were the SMEs ratings of the items?

Q<sub>2</sub>: How well do the SMEs rankings match to the ICTP sequences of the training matrix?

### Participants

This study was conducted with participants from the United States Marine Corp (USMC) 2<sup>nd</sup> Tank Battalion stationed at Camp Lejeune, NC. These participants were Instructor Operators (I/O) and Senior Instructor Operators (SI/O) that supervise and deliver M1A1 AGTS training. They are combat veterans and well-grounded in the training requirements of the M1A1 crew.

Within the USMC there are only 202 M1A1 active duty and reserve unit tank crews combined. From this pool only a few are chosen to be I/Os, and fewer to be SI/O. They are considered to be SMEs by the M1A1 Tank community. Although the M1A1 AGTS is also employed by the US Army and the Saudi Arabian National Guard there may still only be a total of 50 AGTS I/O and SI/O worldwide. Gathering 10% of this population in one place can be considered extraordinary. The researcher was very fortunate and humbled to have this rare opportunity and to be granted access to these five AGTS SMEs from 2<sup>nd</sup> Marine Expeditionary Force (MEF), 2<sup>nd</sup> Tanks Battalion.

Whereas this limited number is a detriment to human subject research, the statistical regime proposed focusses on the algorithm's items not the participants. Each participant provided 260 raw data points resulting in a robust total of 1300 raw data points. These raw data

points, and the hundreds of statistically relevant data points derived from them are the subject of investigation and not the participants, or their reactions.

### Materials and Instrumentation

This section describes the materials and instrumentation used in this study with a special focus on the construction of the revised SC algorithm. This study used four instruments: a Demographics survey, and three phases of SC evaluations. The primary material used during the data collection is the SC overview and “cheat sheet” (Appendix B). The ICTP shown in Figure 5 served as the material to which results of the evaluations were correlated. Since this dissertation’s research questions revolve around the revised SC algorithm, this section also includes a detailed description of the evolution of the SC algorithm.

#### Demographics Survey

The demographics survey includes general questions such as rank, age and length of time in their Military Occupational Specialty (MOS). Participant details assisted in identifying possible explanation for uncovered variances. Results are contained in the Chapter Four and discussed in Chapter Five.

#### The Scenario Complexity Overview and Cheat Sheet

To determine how well the subjective matrix captures the objective level of difficulty, the SME participants (IOs and SIOs) received a period of instruction in identification of scenario base variables that, when calculated using the SC algorithm, determine sub-characteristic, characteristic and total SC values. In addition to this instruction, the participants were also



supplied with a cheat sheet to aid them during each of the three evaluation phases. The instruction and cheat sheet are contained in Appendix B.

### Scenario Evaluations

To answer the first research question each of the SME's participated in three phases of scenario evaluations. These evaluations consisted of a description of the scenario situation, as provided by the ICTP scenario descriptions (Lockheed Martin, 2012) and fields where the SMEs entered their values for the SC base variables. Using these base variables, the sub-characteristics, characteristics and total SC value were derived from revised SC algorithm. During the analysis results from these three scenario evaluations phases were compared for reliability and then correlated to the ICTP matrix.

### The ICTP

To answer the second research question, the SC rankings, as derived from the SME evaluations were correlated to the difficulty rankings as established by the ICTP matrix.

The instructional software embedded in the M1A1 AGTS is intended to present trainees with scenarios as sequenced through the ICTP matrix. This software recommends a trajectory from novice to expert in order for the trainees to achieve the desired Knowledge, Skills and Abilities (KSA). Thus, scenarios are intended to range from very simple to very difficult. However, the ICTP matrix is a result of designer and software engineer subjective perceptions of scenario difficulty.

The ICTP, shown in Figure 5 below, provides entry points where the crew can be inserted into the training system based on current training level. However, once the crew is entered into

the system, only an SIO has the ability to change the location or progression path (Lockheed Martin, 2012).

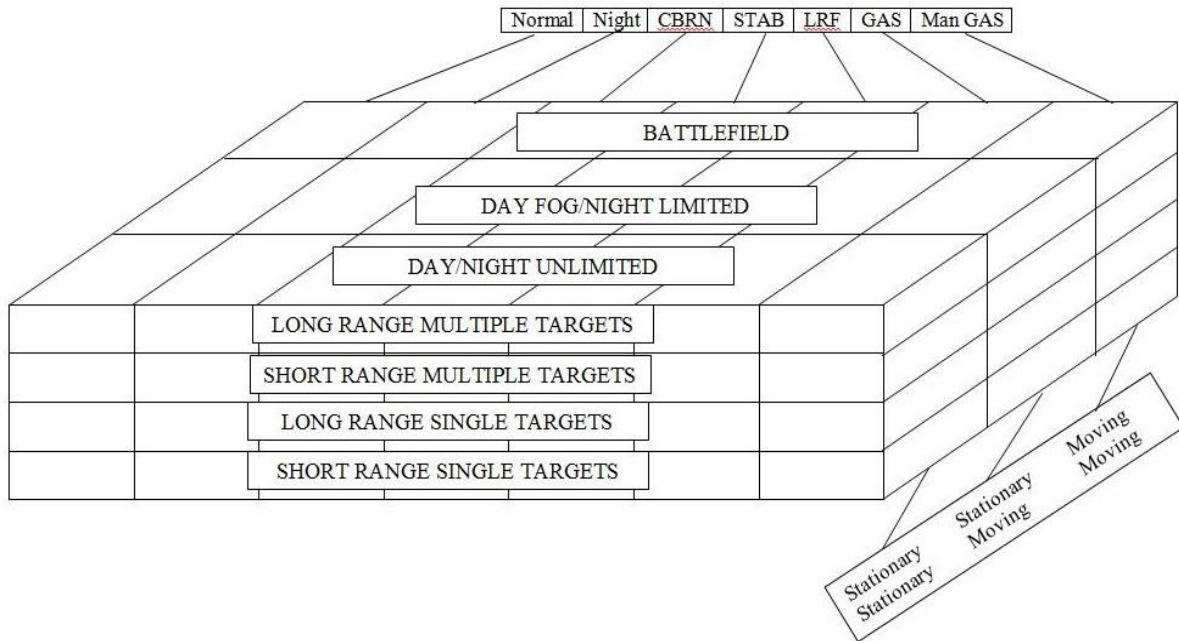


Figure 5: ICTP Matrix

### Revised SC Algorithm

This research is based off a SC algorithm used for a pilot study conducted by the author (Dunne, Schatz, Fiore, Martin et al., 2010; Dunne, Schatz, Fiore, Nicholson et al., 2010). To understand the progression from that algorithm to the equation investigated by this research the following description is provided.

The first SC algorithm consisted of 10 base variables, two sub-characteristics (i.e.,  $TC_1$  and  $TC_2$ ), and three characteristics: Task Complexity (TC), Task Framework (TF), and Cognitive Context Moderators (CCM). The algorithm was formulated as:

$$SC = (TC + TF)CCM \quad (1)$$

The calculation for the TC characteristic was derived from the sum of sub-characteristics  $TC_1$  (i.e., total required acts, total subtasks in each task, plus the number of information cues) and  $TC_2$  (i.e., total subtasks and total of inter-dependent subtasks). The calculation of variable TF was derived from the number of task paths (p) raised by the degree of uncertainty in the paths (u), plus the number of task criteria (o) raised by the number of criteria conflicts (c) plus one.

Table 2: Task Framework Key

TF	sum from i+1 to N of TFi
TFi	$p^u + o^{(c+1)}$
P	# of paths in task i
U	degree of uncertainty in the paths in task i
O	# of criteria that must be satisfied in task i
C	# of conflicts in task i

CCM was simply the degree of stressors from the set {0, 1, and 2} + 1 (since the exponential component of an equation cannot = 0).

The study indicated the equation to be promising, but questions remained. A maximum value and proportion equation analysis was conducted on the original formulation and three salient issues were identified:

- TF\*CCM overpowered  $TC_1$  and  $TC_2$ .
- TF had an exponential growth rate where  $TC_1$  and  $TC_2$  were linear.
- $TC_2$  could not handle the transitive property with respect to inter-dependencies.

Results of the analysis indicated a TF maximum value (limited to 10) to be  $100^{20} + 100^{91}$ . With such a high value, the maximum complexity total was in excess of  $27 \cdot 10^{182}$ . Proportionately, this created an imbalance where maximum TC value accounted for < 1% of the total complexity value.

To address these issues, a modification was made to make the calculation based on a per subtask basis rather than a total task basis. This changed TF to be the sum of intermediate subtask framework values for each task. Secondly, it is assumed that unknown outcomes could actually be a result of conflicting outcomes. Including conflicting outcomes as a unique base variable could be considered redundant. In addition, because the low end ( $\leq 10$ ) maximum calculation allowed sufficient range for granular discernment while using exponential terms above 10 belied the same difficulties recalculation was intended to redress, the conflicting outcomes exponent was removed from the equation altogether and the two base variable terms merged.

Hence a determination is made that any degree of uncertainty/conflict that rose above 10 was calculated not as exponential, but as multiplicative. Trial evidence indicated that modifying inputs that exceeded 10, and were treated by multiplication as opposed to exponentiation, still allowed a range which enabled discernment of a range of complexity. The same trial evidence indicated the base variables associated with  $TC_1$  (i.e., the number of required acts and number of subtasks) became identical when operating with an integrated and complex task –such as those found in the M1A1 AGTS scenarios. Therefore, while it may not be necessary for simple tasks, the redundancy of the base variables became problematic in calculation of total SC. Thus, the number of subtasks base variable was removed from  $TC_1$  but was retained for  $TC_1$  where there was no evidence of redundancy.

These changes significantly lowered the maximum value of TF to  $TF_i = 10^2 + 10^9$  where  $TF = (\text{MAX \# of subtasks}) * TF_i$  or,  $TF = 100,000,001,000$ . This in turn lowered the maximum SC total to a more manageable 2,700,000,027,210. However, this made no significant difference

in proportion as  $TF \cdot CCM$  was still overpowering TC due to the exponential growth of the TF characteristic whereas TC was linearly calculated.

This meant TC would only become significant in scenarios with a low TF value or with just one task and no sub-tasks. Another consequence of this was the complexity value for a scenario was still fairly large. This created the condition where, at a certain point, the desired purpose, and intent of calculating complexity value was lost in dealing with these huge numbers. Such was also the case when the uncertainty/conflict modifying variable exceeded 10.

At this point, methods for reducing the overall complexity value were investigated. One solution was to change the complexity value to logarithmic units similar to the way decibels are calculated to get manageable intermediate values.

Another solution to reduce the overall complexity value was to bound complexity to a range similar to the pH scale. A problem with bounding was complexity can be potentially infinite in the general case. To solve this problem consideration was given to sigmoid functions (von Seggern, 2007) as a way of producing an asymptotic bound. In this way, the closer the value got to this asymptote the more the complexity grew. However, this solution does not affect the intermediate values, which remained unmanageable.

In regards to the issue of growth rate, equations for lowering the growth rate of TF were explored but imbalances still existed due to extremely low calculated values of  $TC_1$  and  $TC_2$ . The elimination of the number of sub-tasks base variable from  $TC_1$  only exacerbated the condition.

Ultimately, none of these ideas balanced  $TF \cdot CCM$  with the TC values. So instead of manipulating the growth of the whole equation or lowering TF's growth, solutions for changing the growth of the overall TC value were explored.

The first important observation was that  $TC_1$  seemed to have a better role as a modifier than  $TC_2$ . Therefore, instead of being a separate term in the SC polynomial,  $TC_1$  was changed to multiply  $TC_2$ . The second important observation was  $TC_2$  did not accurately represent the growth associated with adding more interdependencies between tasks in the scenario. Therefore,  $TC_2$ 's growth was changed to exponential. However, as with the TF variable, at the low end ( $\leq 10$ ) maximum calculation allowed sufficient range for granular discernment while using exponential terms above 10 belied the same difficulties revision was intended to redress.

Similarly, a determination was made that any number of information cues which rose above 10 were calculated not as exponential, but as multiplicative. Trial evidence indicated numbers exceeding 10, and treated by multiplication as opposed to exponentiation, still allowed a range which enabled discernment of a range of complexity.

In the meantime, as with TF, it must be assumed that, if information cues = less than 10, then the level of complexity was less than if the number of information cues was greater than 10 and, as such, may deserve a separate consideration.

Thus:

Table 3: Revised Task Framework Key

TF	sum from i+1 to N of TFi
TFi	$p^u + o$ (while $u = \text{less than } 10$ ) $p * u + o$ (while $u = \text{greater than } 10$ )
p	# of paths in task i
u	degree of uncertainty/conflicts in the paths in task i
o	# of criteria that must be satisfied in task i

- $TC = TC_1 * TC_2$
- $TC_1 = \text{sum of required acts in each task} + \text{sum of information cues}$

- $TC_2 = (\# \text{ subtasks})^{(\# \text{ of interdependent subtasks where } \# \text{ of interdependent subtasks is } 10 \text{ or less})}$
- $TC_2 = (\# \text{ subtasks})^{(\# \text{ of interdependent subtasks where } \# \text{ of interdependent subtasks is greater than } 10)}$

Now TC was comparable to  $TF \cdot CCM$  but  $TC_2$  didn't seem representative of tasks in the scenario that were interdependent. To illustrate; task sets that would have the same complexity value but be very different. Define four tasks A, B, C, and D. Task A is interdependent with task B. Task C is interdependent with task D. The number of interdependent subtasks is 4 in this case since all tasks have a task they are interdependent with. If the interdependencies are changed to make tasks A, B, C, and D all interdependent of each other the number of interdependent subtasks in this case is also 4. The case where all tasks are interdependent should be more complex than the case where two separate sets of tasks are interdependent.

Another problem was if task A was interdependent of task B and task B was interdependent of task C; task A and C should be interdependent since interdependency should maintain the transitive property but the equation didn't model this.

A solution came in finding the number of connected components in the inclusive graph of interdependencies as the way of determining the complexity value for interdependency. This approach could also be rephrased using sets of tasks. For example, in the case of sets  $\{\{A\}, \{B\}, \{C\}, \text{ and } \{D\}\}$  where no tasks are interdependent this set should yield the lowest complexity value. In the case where tasks A and B were interdependent and tasks C and D are interdependent, unions of interdependent tasks would make the task sets look like this:  $\{\{A, B\},$

{C, D}} and, where all the tasks are interdependent, the task set would look like this: {{A, B, C, D}}. Looking at all of these sets the number of items in the top-level set changes.

To calculate complexity, the exponent of  $TC_2$  was defined as: (# of subtasks - # of items in the set of interdependent groupings of the subtasks). Thus, in a set of four tasks where all the tasks are interdependent the exponent will be 3, and in the case of {{A, B}, {C, D}} the exponent would be 2. Another, perhaps easier way to look at this exponent is the number of unions it takes to form the final interdependent groupings. This task grouping method maintains the transitive property for interdependent tasks.

$TC_2 = (\# \text{ subtasks}) ^ (\# \text{ of subtasks} - \# \text{ of connected components in the interdependency graph of the subtasks}).$

Or:

$TC_2 = (\# \text{ subtasks}) ^ (\text{minimal number of unions to obtain the final interdependent task set}).$

The final modification was moving CCM to TC from TF. This was done due to the observation that, as a cognitive modifier, CCM influences the trainee's performance of a task by increasing task and cognitive load, but does not modify the framework of the task which is outside the influence of distractors. That is, no matter the distractors or moderating conditions that are presented, the framework remains static.

Thus, including the variable modifications mentioned, the revised SC algorithm utilized for this study is:

$$SC = TC \times CCM + TF \quad (2)$$



### Ethical Considerations

This study began after obtaining approval from the University of Central Florida Institutional Review Board (Appendix A). All participants were read the researcher's protocol detailing their rights as participants, including the right to withdraw participation at any time without consequence. No potential of harm was present, and all participants were aware of the purpose of data collection. There were no anticipated risks, compensation, or other direct benefits. Participant responses were documented, analyzed and reported anonymously to protect their privacy. All participant data is confidential.

### Procedure

The data collection and research procedure for this study followed three distinct steps: demographic survey, period of instruction, then three scenario evaluation phases.

### Notional Narrative

This section is included in order to illustrate, through narrative, a participant's notional experience.

Staff Sergeant (SSgt) Alpha, an IO for the M1A1 AGTS is sat in a classroom with four other USMC Active Duty M1A1 AGTS IOs and SIOs. He receives greetings, thanks and introduction from the researcher. He is read the researcher's protocol and then given a pen or pencil and a pad of paper followed by an informed consent form. After he signs he is presented with a simple demographics survey that asks him such things as rank, years in service and deployment background.

Upon completion the survey is taken up by the researcher and SSgt Alpha is given a period of instruction on how to identify the base variables of a scenario that determine its level of complexity and a “cheat sheet” that he can use for the rest of the study (Appendix B). At completion of the instruction he is given a 15 minute break.

After he returns, he is given a set of 10 scenario descriptions from the Training System Utilization Handbook (TSUH) (Lockheed Martin, 2012) with fields where he can enter his responses to each of the algorithm’s base variables.

After all participants are finished this phase, the researcher takes his answers up. The researcher then opens the floor to questions and discusses differences in responses to further his understanding. After no more questions the researcher hands him another set of 10 scenario descriptions.

SSgt Alpha repeats this process: evaluation then discussion, twice more.

After completion, time is given for questions, discussion and thanks from the researcher.

### Statistical Analysis

To investigate  $Q_1$  (i.e., How consistent were the SMEs ratings of the items?) generalizability coefficients, derived from implementation of Generalizability Theory (Brennen, 1992) were attained.

Generalizability (G) Theory is a statistical framework for conceptualizing, investigating, and designing reliable observations. It is used to determine the reliability (i.e., reproducibility) of measurements under specific conditions. It was originally introduced in Cronbach, Nageswari, & Gleser (1963). By using G Theory individual formula factors can be examined to determine level of error or importance. G Theory also provides a powerful extension of the

Spearman-Brown "prophecy" formula, enabling the design of efficient data collection plans for specific measurement applications. That is, some factors may be more important in the SC algorithm than others; some may be extraneous.

The G Theory equations in relation to the SC total value and each of the SC components are presented in Chapter Four and Tables 4, 5, 6 and 7.

An often overlooked consideration, in regards to degree of reliability, is the level of acceptability when interpreting results of different types of research. Nunnally (1978) recommends that instruments used in basic research have  $\geq .70$  reliability but increasing reliabilities beyond .80 was unnecessary. However when the research is high consequence, as in the case of research involving aspects of warfighter training, reliability should be at least .90, preferably .95 or better (Nunnally, 1978). Therefore, only reliability levels  $\geq .90$  will be considered very good or acceptable for this study.

To investigate Q<sub>2</sub> (i.e., How well do the SMEs rankings match to the ICTP sequences of the training matrix?) both Spearman's rho and Kendall's tau *b* correlations were conducted to determine correlations between how the SMEs ranked the scenarios in terms of complexity and how the ICTP matrix ranks the scenarios in terms of difficulty.

## CHAPTER FOUR: RESULTS

This chapter presents the results of the Subject Matter Expert (SME) responses and is divided into four sections: 1) introduction; 2) research question one; 3) research question two; and 4) demographics.  $Q_1$  is broken down by total Scenario Complexity (SC), SC characteristics, SC sub-characteristics and SC base variables results. Each of the coefficient sections are delineated time-wise by presenting results, in order, from each of the three data collection phases. The correlation section is like-wise delineated.

### Introduction

The purpose of this research was to examine the efficacy of the SC algorithm to enable Educators or Trainers, Instructional System Designers (ISD) and software engineers to objectively and computationally define SC. Part of this process included a period of instruction given to the participants, Subject Matter Experts (SME), in the identification of the characteristics that comprise the SC algorithm. Using this knowledge, SMEs then determined the values of the SC base variables. These base variables, once calculated, determined the objective total SC values which were then ranked and compared to an existing matrix sequence derived from the Improved Crew Training Program (ICTP) embedded in the Abrams Main Battle Tank (M1A1) Advanced Gunnery Training System (AGTS).

This research is intended to advance the field of Scenario Based Training (SBT) by indicating a method of designing SBT that adapts and automatically initializes, constructs, and sequences scenarios based on trainee performance. With the base variables, and characteristics of the revised SC algorithm this research uses the ICTP matrix as a filter through which the efficacy of the revised SC algorithm are evaluated.

This remainder of this chapter contains three sections; each of the first two sections answers one of the research questions and the third presents results of the demographics survey.

### Q1: How Consistent Were the SMEs Ratings of the Items?

In the case of research involving high consequences, such as research involving aspects of warfighter training, reliability should  $\geq .90$ , preferably  $\geq .95$  (Nunnally, 1978). Therefore, for this study, only reliability levels  $\geq .90$  are considered very good. Thus, results of this research are reported using the following standards of the degree of reliability:  $< .75$  = Poor;  $\geq .75$  but  $\leq .90$  = Modest;  $\geq .90$  = Very good.

### Total Scenario Complexity

After the SMEs had been given instruction on how to identify and enumerate the base variables of the SC algorithm they were given three phases of evaluations that contained 10 scenario descriptions each and were asked to determine and enumerate the base variables present. It is from these values that the total SC is derived.

Table 4 shows the G Theory foundational equation and it's relation to the SC G Theory equation.

Table 4: G Theory as Expressed for SC

G Theory foundation equation	$\rho_i^2 = \sigma_p^2 \div \sigma_p^2 + (\sigma_e^2 \div n_i)$
SC Equation using G Theory	$\rho_r^2 = \sigma_{sc}^2 \div \sigma_{sc}^2 + (\sigma_e^2 \div n_i)$

The G Theory foundation equation is expressed where  $\sigma_p^2$  = the variance of the examinees' universe scores,  $\mu_p$ ;  $\sigma_i^2$  = the variance of the rater means,  $\mu_i$ ;  $\sigma_{e|i}^2$  = the variance of  $e_{pi}$  for rater  $i$ ;  $\sigma_e^2$  = the average over all raters of  $\sigma_{e|i}^2$ ; and  $\sigma_{x|i}^2$  = the variance of  $X_{pi}$  for rater  $i$ ; and  $n$  = number of raters. For the analysis of the G coefficients of the total SC,  $r$  = rater;  $sc$  = SC.

The G coefficients of the total SC values, as derived from the base variables evaluated and enumerated by the SMEs and calculated using the algorithm, were found to be poor in the first phase (.625) modest in the second phase (.872) and very low (.005) in the third and last phase.

### Scenario Characteristics

In the analysis of the G coefficients of the three values of the Scenario Characteristics, determinants of the total SC derived from the identified and enumerated base variables,  $r = \text{rater}$ ;  $_{ccm} = \text{Cognitive Context Moderators (CCM)}$ ;  $r = \text{rater}$ ;  $_{tf} = \text{Task Framework (TF)}$  and  $r = \text{rater}$ ;  $_{tc} = \text{Task Complexity (TC)}$ . Thus the G Theory base variable equations are expressed as:

Table 5: Base Variable Equations

Base variable CCM equation	$\rho^2_r = \sigma^2_{ccm} \div \sigma^2_{ccm} + (\sigma^2_e \div n_i)$
Base variable TF equation	$\rho^2_r = \sigma^2_{tf} \div \sigma^2_{tf} + (\sigma^2_e \div n_i)$
Base variable TC equation	$\rho^2_r = \sigma^2_{tc} \div \sigma^2_{tc} + (\sigma^2_e \div n_i)$

The G coefficients of the Scenario Characteristics values, as derived from the base variables evaluated and enumerated by the SMEs and calculated by using the algorithm, were found to be, in the case of CCM, mixed. In the first phase the responses were sufficiently restricted in range as to render determination of consistency moot. That is, where the range of possible responses is restricted, and the responses almost identical, no reliable or valid determination of consistency is available; enough variance was present in the second phase to indicate poor (.490) and excellent (1.00) in the third and last phase.

The TF G coefficients were very good (.923) in the first phase but dropped to poor (.716) and (.625) in the second and third phase respectively.

In order of phase, G coefficients for TC were poor (.625) very good (.902) and poor (.005).

### Scenario Sub-Characteristics

To analyze the G coefficients of scenario Sub-Characteristics that comprise the TC characteristic,  $r$  = rater;  $cc$  = Component Complexity and  $r$  = rater;  $coord$  = Coordinative Complexity. Thus the G Theory equations are expressed as:

Table 6: G Theory Sub-Characteristic Equations

CC Sub Characteristic	$\rho^2_r = \sigma^2_{cc} \div \sigma^2_{cc} + (\sigma^2_e \div n_i)$
Coord Sub Characteristic	$\rho^2_r = \sigma^2_{coord} \div \sigma^2_{coord} + (\sigma^2_e \div n_i)$

The G coefficients of Component Complexity and Coordinative Complexity, derived from the base variables, and sub-characteristics of the TC Characteristic were revealed to be, in the case of Component Complexity, very good in all three phases (.989), (.990) and (.996) respectively. Coordinative Complexity G coefficients showed as poor in first phase (.625) very good in the second (.907) and poor again (.623) in the third and last phase.

### Scenario Base Variables

The G coefficients for the eight base variables use the following:  $r$  = rater;  $a$  = required acts,  $r$  = rater;  $ic$  = information cues,  $r$  = rater;  $st$  = sub-tasks,  $r$  = rater;  $idt$  = interdependent tasks,  $r$  = rater;  $tp$  = task paths,  $r$  = rater;  $tc$  = task criteria,  $r$  = rater;  $ucp$  = unknown/conflicting paths,  $r$  = rater;  $d$  = distractors. The G Theory equations for these base variables are expressed as:

Table 7: Base Variable G Theory Equations

Required acts equation	$\rho_r^2 = \sigma_a^2 \div \sigma_a^2 + (\sigma_e^2 \div n_i)$	Task paths equation	$\rho_r^2 = \sigma_{tp}^2 \div \sigma_{tp}^2 + (\sigma_e^2 \div n_i)$
Information cues equation	$\rho_r^2 = \sigma_{ic}^2 \div \sigma_{ic}^2 + (\sigma_e^2 \div n_i)$	Task criteria equation	$\rho_r^2 = \sigma_{tcr}^2 \div \sigma_{tcr}^2 + (\sigma_e^2 \div n_i)$
Sub-tasks equation	$\rho_r^2 = \sigma_{st}^2 \div \sigma_{st}^2 + (\sigma_e^2 \div n_i)$	unknown/conflicting paths equation	$\rho_r^2 = \sigma_{ucp}^2 \div \sigma_{ucp}^2 + (\sigma_e^2 \div n_i)$
Interdependent tasks equation	$\rho_r^2 = \sigma_{idt}^2 \div \sigma_{idt}^2 + (\sigma_e^2 \div n_i)$	Distractors equation	$\rho_r^2 = \sigma_d^2 \div \sigma_d^2 + (\sigma_e^2 \div n_i)$

Each of the scenario Base Variable value G coefficients, evaluated and enumerated directly by the SMEs, were calculated and, in order of phase, were shown to be very good for all three phases of the Required Acts base variable (.981, .987 and .998), very good for all three phases of the Information Cues base variable (.966, .977 and .990) again, very good for all three phases of the Sub-Tasks base variable (.986, .939, .998) all three phases of Interdependent Tasks were also very good (.982, .944, .998). Task paths continued the trend with very good G coefficients for all phases (.948, .917, and 1.00). Task Criteria yielded excellent and very good results (1.00, .928 and 1.00) as did Unknown/Conflicting Paths (1.00, .920, .998). The Distractors G coefficients varied from the first phase, where execution was stopped to a second phase poor (.363) and final phase excellent (1.00).

Table 8 below summarizes these findings.



Table 8: Summary of Generalizability Coefficients by Evaluation Phase

Evaluation Phase	1	2	3
	G coefficient	G coefficient	G coefficient
Total Scenario Complexity			
SC	.625	.872	.005
Characteristics			
CCM	*	.490	1.000
TF	.923	.716	.625
TC	.625	.902	.005
Sub-Characteristics			
Component Complexity	.989	.990	.996
Coordinative Complexity	.625	.907	.623
Base Variables			
Acts	.981	.987	.998
Cues	.966	.977	.990
SubTasks	.986	.939	.998
InterDependentTasks	.982	.944	.998
Task Paths	.948	.917	1.000
Task Criteria	1.000	.928	1.000
Unknown/Conflicting Paths	1.000	.920	.998
Distractors	*	.363	1.000

\* Responses were too restricted in range to allow determination of variance

## Q2: How Well do the SMEs Rankings Match to the ICTP Sequences of the Training Matrix?

Correlation of SME scenario complexity evaluations, as derived from their objective calculations to the subjective sequencing of the ICTP matrix was conducted in three stages; each phase's results were then correlated by SME to ICTP sequencing.

Table 9: SME to Matrix Ranking Correlations

	Phase 1		Phase 2		Phase 3	
SME	SME to Matrix Kendall's tau <i>b</i>	SME to Matrix Spearman's rho	SME to Matrix Kendall's tau <i>b</i>	SME to Matrix Spearman's rho	SME to Matrix Kendall's tau <i>b</i>	SME to Matrix Spearman's rho
1	.102	.110	-.398	-.500	.000	-.018
2	-.114	-.183	-.613	-.759	-.225	-.274
3	-.045	-.140	-.660	-.821	-.225	-.274
4	-.047	-.093	-.349	-.462	.022	-.018
5	-.047	-.093	-.210	-.295	.022	-.018

In evaluation phase I SME 1 had a significant correlation at the .01 level to SMEs 4 and 5 (.915 and .952 respectively). This means that over 90% of the time, they agreed as to the sequencing of the scenarios. SME 4 had a significant correlation at the .01 level to SME 5 (.830).

SMEs 1 and 2 had a significant correlation at the .01 level (.806). There was no significant correlation between the ICTP matrix sequencing and any of the SMEs.

In evaluation phase II SME 1 had a significant correlation at the .01 level to SMEs 2 and 4 (.903 and .964 respectively) and a significant correlation at the .05 level to SME 5 (.661). This means that over 90% of the time, SMEs 1, 2 and 4 agreed and over 60% of the time SME 1 and 5 agreed to the sequencing of the scenarios. SME 2 had a significant correlation at the .01 level to each of the other SMEs. The ICTP matrix was significantly negatively correlated to each of the SMEs showing the greatest negative correlation to SME 2 (-.636).

In evaluation phase III SME 1 had a significant correlation at the .01 level to SMEs 4 and 5 (.952) and a significant correlation at the .05 level to SME 2 (.648). This means that over 90% of the time, SMEs 1, 4 and 5 agreed and over 60% of the time SME 1 and 2 agreed to the sequencing of the scenarios. SME 2 and 4 had 100% agreement (1.00) and SME 3 and 2 had a significant correlation at the .01 level (.988). The ICTP matrix was significantly negatively correlated to SME 2 and 3 (-.139 and -.188).

### Demographics

The demographics survey results, shown in Table 4, include general questions such as rank, age, and length of service. These results help to uncover level of experience with the

AGTS, level of warfighting experience and frequency of their training duties in order to address any anomalies that may arise during data collection or data analysis.

Table 10: SME Demographics

<b>ID</b>	<b>Age</b>	<b>1 = LCPL 2 = CPL 3 = SGT 4 = SSGT</b>	<b>Years in Service</b>	<b>Primary Crew AGTS position 1 = GNR 2 = TC</b>	<b>Deployed Overseas 1 = Yes 2 = No</b>	<b>0 = no, 1=Afghanistan 2=Iraq 3=Iraq and Afghanistan</b>	<b>Directly Responsible for training other Marines 1 = Yes 2 = No</b>	<b>If Yes how often 1 = Daily 2 = Once a Week 3 = Once a Month 4 = Less Often</b>	<b>If Yes, how long an instructor</b>	<b>Are you a certified I/O 1 = yes 2 = no</b>
SME1	27	3	9	2	1	3	2	1	3	1
SME2	29	4	11	2	1	3	1	2	5	1
SME3	25	1	3	1	1	1	1	1	.83	1
SME4	26	1	3	1	1	1	1	4	2	1
SME5	27	3	9	2	1	2	1	1	4	1

## CHAPTER FIVE: DISCUSSION

This chapter summarizes and discusses this study's results and is divided into eight sections. Section one presents a brief overview of the study; section two discusses the limitations relative to the study's methodology and results; section three presents a discussion of the results for research question one with results for research question two presented in the fourth section. Significance of these findings for Educators and Trainers, Instructional System Designers (ISD) and Researchers are described in section five. Section six discusses implications for four areas (i.e., the SC algorithm, serious games, academia, Military) and section seven presents recommendations that focus on future research, section eight presents recommendations that focus on practice and a brief summary and conclusion is in section nine.

### Overview of Study

The Military has been at the forefront of Scenario Based Training (SBT) since the first flight simulator was adopted in 1934 (Link, 2009) and continues to incorporate simulation and associated instructional software into their Programs of Instruction (POI).

At the core of United States Marine Corps (USMC) training is the instructional strategy of “crawl, walk, run”. The “crawl, walk, run” approach creates training trajectories that require acquisition and maintenance of knowledge, skills, and abilities (KSA) at ever advancing levels. This is a standard instructional strategy in the US Army and USMC and is supported by learning theories described by Vygotsky (1972) and Krashen (1982). However, in this technologically advanced era progression of training difficulty continues to be based on subjective perception. If effective sequencing of SBT is to be ensured, training progression must stem from a scenario's

objective level of complexity; a value, or operational sum that can be objectively determined and computationally actionable.

To computationally define Scenario Complexity (SC) this author developed an algorithm that included characteristics such as: Task Complexity (TC), Task Framework (TF) and Cognitive Context Moderators (CCM). These characteristic's values were derived from base variables including number of sub-tasks and conflicting outcomes that, in turn, enabled calculation of total SC. Two papers document these efforts and results: Dunne, Schatz, Fiore, Martin et al., (2010) and Dunne, Schatz, Fiore, Nicholson et al., (2010).

Outcomes of those efforts indicated promising results, and further analysis of the algorithm led to the revisions of the SC algorithm researched for this dissertation.

The purpose of this research was to examine the efficacy of the revised SC algorithm to enable Educators or Trainers, ISD and software engineers to objectively and computationally define SC. Part of this process included a period of instruction given to the participants, Subject Matter Experts (SME), in the identification of the base variables that comprise the SC algorithm. Using this knowledge SMEs then determined the values of the SC base variables. These base variables, once calculated, determined the objective total SC values which were then ranked and compared to the existing training matrix sequence of the Improved Crew Training Program (ICTP) embedded in the Abrams Main Battle Tank (M1A1) Advanced Gunnery Training System (AGTS).

To automate and, more importantly, adapt to the performance of the trainee software solutions must be in place to computationally define SC value and prescribe the complexity level

of the follow-on scenario according to conceptual frameworks as described by Vygotsky's Zone of Proximal Development and Krashen's  $i+1$ .

Dunne, Schatz, Fiore, Martin et al. (2010, p. 2) assert "it is crucial to objectively define and instantiate scenario complexity so the software can calibrate and assemble appropriate SBT episodes. Successful instantiation depends on creating an objective computational metric of the subjective notion of difficulty".

### Limitations

The integrated learning domains and expansive task-specific components researched here, while enabling a very large data set, were also very problematic. The highly proceduralized tasks allowed for a high degree of agreement among participants. That is, it is possible subjectivity played a less influential role here than it may in other circumstances and within other domains.

In any case, a greater number of participants would benefit the determination of generalizability. It was simply not possible to gather a larger contingent of SMEs.

Also, as it was beyond the scope of the investigation, no attempt at a longitudinal design to determine if the lessons learned by the participants continued over time, or that they employed those skills in the design and sequencing of their own instruction. In addition, turning the experiment around and asking other SMEs to subjectively verify the sequence objectively determined by these SMEs was not conducted but would be a next step for future research.

Results also indicate an important consideration that was not accounted for: fatigue. Due to the schedule and limited availability of these SMEs this research needed to be conducted within a compressed time frame. Each of the three phases lasted at least 45 minutes. Results

from the third and last phase are, in some cases, less consistent than the others even though an upward trend had been previously indicated. Future research of this type should account for the extensive cognitive resource requirements.

#### Discussion of Q1: How Consistent Were the SMEs Ratings of the Items?

Generalizability (G) coefficients were used to determine the consistency of the SME responses. The closer the G coefficient is to 1.0 the greater the consistency of the items in the scale. Nunnally (1978) recommends that instruments used in basic research have  $\geq .70$  reliability but  $\geq .80$  reliability is unnecessary. However when the research is high consequence, as in the case of research involving aspects of warfighter training, reliability should be  $\geq .90$ , preferably  $\geq .95$ . Therefore, for the purpose of this studies results and discussion, only consistency levels  $\geq .90$  are considered very good or acceptable.

The results of the G study affirm that the SMEs were consistent in their rating of the items across scenario base variables and, in most cases, increased from phase to phase. However, trends also indicate that this consistency loses potency with successive algorithm functions. It is reasonable to expect that with such a strong, consistent foundation the upward results would be of equal consistency, but this was not the case. It may be concluded that further modification of the algorithm would yield more robust results.

For example, results of the first phase of the distractors base variable indicated that the SME were unable to distinguish any difference in the level of distraction among any of the 10 scenarios investigated in that phase. After examining the outputs it can be concluded that the range of possible responses (1-3) is too restricted to allow reliable responses. A greater degree of granularity and a higher level of definition regarding the moderators that influence cognitive



processing is necessary to allow a wider range of possible responses. Accounting for such things as crew discipline and personnel levels of experience, concurrent environmental states and level of battle chatter and obstacles will increase the range of distractor value possibility. Beyond the scope of this research, however a field of potentially significant findings, considering the psychological states of the crew, such as stress, complacency, and confidence may also allow a greater range of distractor values.

The CCM characteristic has exhibited itself to be of greater potential impact than originally accounted for and greater granularity of the values will increase effectiveness of the algorithm. Further modification of this characteristic within the algorithm would be beneficial.

Consistency is greatest among SMEs 1, 2 and 5. SMEs 3 and 4 are more consistent between themselves. Results of the demographic responses show that the ranks of SMEs 1, 2 and 5 were either Sergeant or Staff Sergeant with the primary crew position of Tank Commander (TC). SMEs 3 and 4 were Lance Corporals with the primary crew position of Gunner (GNR). This suggests that the TC, even when evaluating a gunnery-intensive situation, has a more complete or holistic appreciation of the minutia involved for successful completion of the task. Furthermore, SMEs 3 and 4 had the least amount of M1A1 AGTS Instructor/Operator (IO) experience (i.e., less than a year and one year respectively). SME 4 also responded that he was only responsible for training once a month. It is therefore reasonable to assume that with greater experience, preferably in the position of TC, an IO or SIO would respond with even greater levels of consistency.

Results also suggest that the coordinative complexity sub-characteristic outweighs the other factors and plays an undue role in the calculation in the final SC value for as goes the Task

Complexity characteristic that is comprised of the coordinative complexity sub-characteristic so, it appears, goes SC. This should not be the case in a properly weighted equation. Further analysis of and research into the equation is warranted.

### Discussion of Q2: How Well do the SMEs Rankings Match to the ICTP Sequences of the Training Matrix?

The most salient implication of this research's results is that the ICTP matrix sequencing deviates significantly from and does not correlate to the SME sequencing derived from the SC algorithm. It was expected that there was going to be some deviation from the subjective sequencing as designed by software engineers and the scenario sequencing as revealed my SMEs instructed in the identification and enumeration of scenario base variables. However, the degree of disagreement is alarming. In such a high consequence environment where the sequencing of training is vital; the "crawl, walk, run" strategy, supported by Vygotsky and Krashen, must be adhered to. Instead, results indicate this doctrinal strategy is fatally violated.

### Significance

#### Significance for Educators/Trainers

For the purpose of this section, the term Educator and Trainer are used interchangeably. The use of SBT is not confined to either academic or Military applications. The implications and significance of this research are indistinguishable from one sector to the other.

The significance of results of this research is three-fold. First, students will receive instruction that challenges them and presents them with scenarios that increase their archive of experiences. Second, implementation of the SC algorithm may reduce training time and expense while increasing trainee throughput. Finally, with automated, adaptive scenario sequencing

instructors will be free to pay more attention to the details of the trainee's performance, targeting feedback and personalizing exercise instruction.

One of the strengths of SBT is the presentation of varied situations that allow trainees to experience real-world problems prior to engagement. Through such training, personnel learn to integrate multiple skills, cope with realistic distracters, practice their higher order cognitive skills, and exercise naturalistic decision-making (Cannon-Bowers & Salas, 1998).

For example, Klein's Recognition-Primed Decision framework (1989) proposes that experts make decisions by recognizing similarities between current decision situations and previous decision experiences. Trainees and students, once in the "real-world" are often presented with situations that they have not experienced before. SBT can help mitigate this gap. By adapting scenario complexities and automating generation, trainers can provide a greater variety of appropriately calibrated training events, thus broadening their repositories of experience (Dunne, Schatz, Fiore, Nicholson, et al., 2010).

Where there is no automation, SBT scenarios are chosen by the trainer based on training objectives, a description of the scenario (if present), the trainees' level of experience, and timeline requirements. Although training manuals may present sequences of training, they typically lack explicit recommendations for sequencing of scenarios. Trainers must then rely on subjective judgment. Where automation of sequencing is available, the sequencing, as has been found by this researcher and discussed in a later section, is problematic. Consequently, a trainer's sequencing may not align with trainees' levels of experience or performance, and mismatching trainees with training events can result in negative learning, inefficient timelines and increase in expense.

Findings from this research will potentially impact delivery of online and computer based instruction, making it easier to automatically adapt delivery of instruction to the individual learner's needs. The National Education Technology Plan (NETP) recognizes, "The challenge for our education system is to leverage the learning sciences and modern technology to create engaging, relevant, and *personalized* (italics are the author's) learning experiences for all learners..." (NETP, 2010). One-size-fits-all content presented in lock-step linear design does not answer this challenge.

Perhaps most importantly, automating the process of sequencing, adapting the POI by computational means, creates a seismic shift in role definition as instructors and educators take on a facilitative and diagnostic role rather than that of the originator and provider of content. This requires a significant adjustment in culture and philosophy for educators and trainers as well as upstream adjustment in approaches to curriculum for administrators.

### Significance for Instructional System Designers

Reiser (2001) stated the following:

Instructional design and technology encompasses the analysis of learning and performance problems, and the design, development, implementation, evaluation and management of instructional and non-instructional processes and resources intended to improve learning and performance in a variety of settings, particularly educational institutions and the workplace. Professionals in the field of instructional design and technology often use systematic instructional design procedures and employ a variety of instructional media to accomplish their goals. (p. 53)

Embedded in Reiser's definition is a systematic process known as ADDIE; analysis, design, development, implementation and evaluation (Dick, Carey & Carey, 2009).

The significance of the results of this research touches upon each of these phases of the ISD process. The responsibilities of the ISD of SBT that incorporates this algorithm will expand to include analysis of each of the base variables, sub-characteristics and characteristics of the tasks contained in the scenario. In order to fulfill this requirement, the ISD will have to be well-versed in definition and identification of the SC characteristics. In addition, when working with SMEs, giving them instruction regarding SC characteristics will be required.

The ISD must design tasks which are authentic, and replicate the cognitive demands of the real world (Savery & Duffy, 1995). Utilizing findings from this research to design scenarios will require incorporating increasing complexities by manipulation of the SC base variables while at the same time maintaining a manageable range of complexity to ensure sequencing (remedial or advancement) does not violate grounded learning theory and demotivate the learners.

Software solutions, such as the researched algorithm, must then be put into place to develop the POI and allow for automation. If the developer is not the designer themselves translation of specifications requires a clear framework of understanding between the two agents. The onus of this responsibility falls upon the ISD and a thorough understanding of the complexities of this process is paramount; the ISD must be cognizant of the interaction of the base variables and their influences upon the SC value and be able to articulate them to the developer.

Some investigators have found that, when implemented, automation may actually increase workload, inviting occasions for new errors (Wiener, 1989; Kurlik, 1993; Sarter & Woods, 1995) and situations which the designer must take into account. Automating and

adapting the sequencing of content will require changes in the way instructor activities are carried out, the order and timelines of content delivery and this introduces a new set of problems (Wiener & Curry, 1980; Billings, 1991; Woods, 1996) for which the ISD must be prepared.

Evaluations of SC-based SBT should include determining the appropriateness of how the scenario sequencing interacts with the characteristics of the learner. This will be vital to verify and validate the original design and range of complexities presented during the POI; the prescribed follow-on scenario being just a little harder than the scenario before or, if a trainee demonstrates a level of performance that prescribes a remedial scenario, the scenario is just a little easier than the preceding one.

Employing SC into SBT will require the ISD to ensure content aligns with performance by attending to a unique and unfamiliar specification; operational requirements of the sequencing engine. However, the complexity of possible interactions across key variables, as implemented by the sequencing engine, is restricted only the number of scenarios and imagination of the designers or developers.

Recalling Lantolf's description of the differentiation between  $i+1$  and ZPD, in light of this research this author asserts that in SBT, where experiential learning forms the paradigm and intentional educational development the objective, Lantolf's attempt to differentiate these two concepts dissolves. That is, if one accepts Lantolf's description, then in SBT environment,  $i+1$  and ZPD encompass and fulfill the same intentions. A reconceptualization of these two concepts, at least in their application to SBT, is in order.

This author proposes the term *zone of acquired complexity* as definition of the zone of SC values within which the trainee has demonstrated acquisition of KSA, and further proposes the

term *zone of comprehensible complexity* as definition of the zone of SC values within which constructs, structures and KSA are just beyond the trainee's level (Krashen, 1982) and yet still at the level of potential development (Vygotsky, 1978). These proposed definitions may aid in the construct of SBT design and scenario sequencing.

Beyond the employment of the proposed algorithm and results of this research, it is hoped that ISDs will consider, revise and extend these findings into their respective fields in order to deliver more efficient and effective SBT.

### Significance for Researchers

This study extends adaptive automation literature and increases understanding of the growing use of SBT. Results from this research indicate additional avenues of investigation into the characteristics, utilization, and implementation of the SC algorithm. Other fields may benefit from examining how SC-based SBT may aid in training higher-order thinking skills, which is itself an emerging focus of research interest (Tichon & Wallis, 2010). Researchers investigating topics such as automation or adaptivity, or both, who raise questions such as, “whether/or ...”, “when to/not to ...” may find operationalization of the SC algorithm to be an integral piece of their puzzle.

As mentioned in the previous section significance of this study touches upon all areas of the ADDIE process and researchers may find fertile fields of study in areas that will assist ISDs in each of those areas as well. Also mentioned in the previous section this author proposes the term *zone of acquired complexity* as definition of the zone of SC values within which the trainee has demonstrated acquisition of KSA, and further proposes the term *zone of comprehensible complexity* as definition of the zone of SC values within which constructs, structures and KSA

are just beyond the trainee's level. Investigating the appropriateness, and accuracy of these proposed definitions in regards to SBT opens further avenues of research to extend instructional theory.

Researchers may choose to identify best practices when giving instruction to SMEs where SC characteristics are concerned. Training effectiveness evaluations may require researchers to verify and validate that the designed tasks are actually authentic, and replicate the cognitive demands of the real world (Savery & Duffy, 1995) and whether the sequencing of content employs the SC base variables soundly to increase or decrease complexities as appropriate. Researchers may also be called upon to instantiate and evaluate the developed software solutions required of the proposed, or other such, algorithms. When implemented, researchers may seek to determine the influence of SC automation on workload; studying to see if SC-based SBT invites occasions for new errors (Wiener, 1989; Kurlik, 1993; Sarter & Woods, 1995).

Researchers may find objective basis for supporting what are, ultimately, subjective prescriptions such as Vygotsky's ZPD (1978) and Krashen's *i+1* Theory of Learning and Acquisition (1982).

The literature review conducted for this research indicates that research at the intersection of adaptive instruction, SC and SBT is embryonic. For researchers, a new avenue of study is an energizing, clear call for investigation. This study, and its outcome, supports such investigation and begins to fill a vital gap in the research literature. Beyond the employment of the proposed algorithm and results of this research, it is hoped that researchers will revise and extend these



findings and the studied algorithm into their respective fields in order to deliver more efficient and effective learning.

### Implications

This section discusses implications to four areas: the SC algorithm itself and three sectors that employ SBT (i.e., serious games, academia and the Military).

#### SC Algorithm

Outcomes from this research have direct implications to the SC algorithm. Findings suggest that equation weighting needs to be reassessed; particularly in the area of CCM. A more granular and less restricted range of possible values would be of benefit to the consistency and reliability of the equation and total SC value. Perhaps the actual number of distracting factors be enumerated and used as the variable value. This would give CCM a larger moderating role and remove statistical limitations resulting from restricted CCM level.

Merging the original algorithm's base variable of uncertain (unknown outcomes) linkages to conflicting criteria may need to be reassessed. Since ambiguity affects the ease of completing all subtasks and requires actors to devote substantial cognitive resources to actions such as problem solving, analysis, and decision making, to account for such compounding, uncertain linkages may be an appropriated modifier to CCM instead of being removed entirely.

Demographics have shown that level of experience influences the perception of the scenario requirements and therefore the tasks' components. Consideration must be given to how much of a role experience plays when the IO sequences their exercise scenarios.

The SC algorithm can be considered a partial training equation. That is, it designed and intended to account only for the tasks that are conducted and experienced by a single trainee and does not integrate other trainee's tasks. Extension of this algorithm to a larger, more complete training equation that incorporates a whole team is a likely avenue of future research.

Trial evidence indicated that modifying inputs exceeding 10, and treated by multiplication as opposed to exponentiation, still allow a range which enables discernment of a range of complexity. This introduces and raises the question of: at what point does the objective complexity construct break down to subjective terms such as: *least*, *average* and *extreme*?

### Serious Games

When playing a digital game one is presented with a stage, or assessment, after which one continues to the next "page" or scenario. This remains as static a delivery as the linear progression of traditional learning; no adaptability. Implementing a dynamic scenario creation engine that bases the sequencing on performance of the players will, as in SBT that implements the same capability, ensure each successive stage maintains motivation. Often, after easily defeating one level's boss player are presented with the next, linearly defined boss, only to find they present little to no challenge, as does the next ... and the next. Or, conversely, no matter what you do, you cannot defeat the lower level boss but are presented with the same situation, the same scenario, with no deviation, over and over and over and over. In all cases, automated, adaptive sequencing would prevent the "toss-aside" effect where a game or simulated situation is either too hard or too easy so the player, learner or trainee simply toss aside -either figuratively or literally- the game, module or program.

## Academia

Something Education can learn from business is that Education needs to make fundamental changes that allow technology to engender improvements (NETP, 2010). The more technology is incorporated into the schools the more it must be recognized that although the fundamental purpose of the education system remains the same, the roles and processes of schools and educators, must change to reflect the times. That is, rather than the providers of knowledge, Educators will be more appropriately aligned as a facilitator of knowledge. SBT brings Dewey's education of experience closer to realization.

Additionally, the NETP recognizes, "The challenge for our education system is to leverage the learning sciences and modern technology to create engaging, relevant, and *personalized* (italics are the author's) learning experiences for all learners" (2010). With reliable, instructionally sound sequencing of scenarios, aligned to the performance of the individual, the one-size-fits-all traditional presentation of content will be supplanted.

Such a shift in the instructional process, automating content sequencing by computational means, creates a seismic shift in role definition as instructors and educators take on a facilitative and diagnostic role rather than that of the originator and provider of content. This requires a significant adjustment in culture and philosophy for educators and trainers as well as upstream adjustment in approaches to curriculum for administrators.

## Military

The current fiscally restrained environment reduces availability of operational funds related to live training in general and gunnery qualification in particular. Thus, it can be assumed the cost avoidances that define simulation, will support increase in implementation of

additional SBT systems. Automating sequencing of scenarios reduces work-load upon the IO thereby enabling them to pay attention to detailed areas of instruction, increasing trainee throughput thus avoiding live-fire costs.

Beyond the immediate implications of this research and realizing the stated initiatives of the Military to move toward a Live, Virtual and Constructive (LVC) training environment efforts in the near future may be directed toward a collective, rather than singular definition of SC.

Previous work focused on the mathematical representation of the complexity level of a single scenario. Extending this SC formula to account for the nonlinear increase in scenario complexity that occurs during multiple scenario integration is a likely downstream avenue of research.

This formulation was expressed within the framework of a single string. That is, the sequencing of scenarios was based on a ground-up approach from novice to expert bounded by a single learning objective (i.e., advanced gunnery). This single string approach assumes two things, 1) a single task is the training objective and 2) no extra-task objectives are required.

Progression along a single-string trajectory is relatively simple when compared to progression along a multiple-string trajectory. Multiple-string progression is the change in knowledge, skills and attitudes across tasks within and across domains.

For example; sequencing scenarios that guide a trainee through the steps of Call-For-Fire (CFF) are in single-string until the introduction of other tasks such as Close Air Support (CAS) or Helicopter Evacuation (HELIVAC). At that point the CFF trainee must integrate their previous experience, if any, in multiple domains. In addition, the trainee may be a novice at CAS, an expert at CFF and only possess intermediate knowledge of HELIVAC, yet they must

accommodate the new situation and conditions, and perform multiple tasks to attain multiple objectives.

Validation of this formulation's capability to discriminate between scenarios of differing complexity as well as its successful identification of appropriate scenarios for adaptation based on performance levels is another area of future research and experimentation.

Modeling and simulation sector articles focus on the technological aspects of the sector and give little attention to the educational. A brief review of professional magazines finds articles on training trends and hardware or software advances but no mention of advances or needs found regarding the delivery or content of training materials or content. During personal experience in the acquisition sector attention is significantly oriented to the engineering or physical attributes and requirements; training and instruction is almost an after-thought.

It is also possible that with successful extension of this research, complete automation could be achieved enabling effective and efficient training.

### Recommendations for Future Research

Although there are many potential avenues of research results of this study point to, in addition to continued assessment of this SC algorithm, the following recommendations are forwarded and focus on future research.

- It is recommended to extend research from the single scenario definition of SC toward a collective definition.

This study and the previous work it was built upon focused on the computational definition of the complexity level of a single scenario. Extending this SC formula to account for

the increase in SC that occurs during multiple scenario integration could advance current Military initiatives towards LVC training environments.

- It is recommended that further research be conducted to more finely tune the equation by reassessing each of the base variables and considering additional adjustments to the algorithm.

Results from this research indicate additional avenues of investigation into the characteristics, utilization, and implementation of the SC algorithm. The primary avenue is in closer examination of the equation in light of this study's results. For instance, the algorithm may be sufficient for a declarative or procedural domain but adjustments may be required to address other domains that include higher-order thinking skills.

- It is recommended that research be conducted implementing the algorithm with a sufficiently sized library of scenarios to compare to a control group using an otherwise sequenced matrix.

Research into the effectiveness of an SC algorithm-derived training sequence would be the logical next step to put theory into practice.

- Research that uses the findings here to determine if other SMEs would be more closely aligned with each other in regards to the sequence of scenarios as determined by these SMEs or the ICTP.

An effort such as this would help validate and verify this study's findings as well as support future practice by providing a level of confidence to practitioners.

- In sum, results of this study indicate an avenue of study that can lead to significant advances in SBT.

This study, and its outcome, has extended SBT research and helped to fill a vital gap in the research literature. Beyond the employment of the proposed algorithm and results of this research, it is hoped that researchers will revise and extend these findings into their respective fields in order to deliver more efficient and effective learning.

### Recommendations for Future Practice

The following recommendations are forwarded as result of the findings of this G study and are focused on the findings' impact on future practice.

- It is recommended that a POI be developed for new IOs and SIOs to instruct them on how to identify the important characteristics (base variables) of a scenario that form the basis of its level of complexity.

This research has shown that SMEs at this level who are engaged in high-consequence training already possess a significant level of agreement when it comes to understanding the requirements of the tasks that they set before their trainees. Recall how, in many cases, they were already significantly consistent ( $\geq .70$ ) for Phase 1. However, because of the survivability and lethality aspects of this training and according to Nunnally (1978) .70 is not good enough. That is, where lives are on the line the level of consistency must be appropriate to the stakes. With aid of the algorithm and the instruction that they were presented with, SME became even more consistent with their ratings and attained levels of consistency more appropriate ( $\geq .90$ ). A POI that includes such information may have significant downstream impact.

- Implementation of software solutions that automatically create and sequence scenarios adapting to the performance of the trainee and adhering to grounded instructional strategy and learning theory.

This author defined *zone of acquired complexity* as the zone of SC values within which the trainee has demonstrated acquisition of KSA, and the *zone of comprehensible complexity* as the zone of SC values within which constructs, structures and KSA are just beyond the trainee's level (Krashen, 1982) and yet still at the level of potential development (Vygotsky, 1978). These terms may be appropriate descriptors of the relatively new instructional paradigm created by SBT. Together with an objective value of scenario complexity, sound instructional strategies and grounded pedagogical practices may be implemented into a growing and dynamic training practice.

- It is recommended that the ICTP be reevaluated and redesigned using the SC algorithm.

As shown by the results of the correlations, the SMEs rankings of the level of complexity of the scenarios were alarmingly different than the rankings of difficulty as contained in the ICTP. In light of these results it would be accurate to say the ICTP is clearly misaligned to the “crawl, walk, run” instructional philosophy. To increase training fidelity and to optimize the matrix, a redesign of the matrix is suggested.

### Summary and Conclusion

The purpose of this research was to examine the efficacy of the SC algorithm to enable Educators or Trainers, ISD and software engineers to objectively and computationally define SC. Part of this process included a period of instruction given to SMEs, in the identification of the characteristics that comprise the SC algorithm. Using this knowledge SMEs then determined the values of the SC base variables. These base variables, once calculated, determined the objective total SC values which were then ranked and compared to an existing matrix sequence derived from the ICTP embedded in the M1A1 AGTS.



This research advances the field of SBT by suggesting a method of designing SBT that adapts and automatically initializes, constructs, and sequences scenarios based on trainee performance and grounded by researched instructional strategies and learning theory. The SC algorithm enabled an objective ranking of scenario values which was correlated to the the ICTP matrix.

This research found that the SMEs were very consistent in their ratings of the items across the scenario base variables of the proposed SC algorithm and the ICTP matrix was significantly misaligned to the SC algorithm sequencing.

More research is necessary but promising directions have been shown. Whether these future efforts are conducted by this researcher or others who take up the call the outcome will be additional contributions to the ISD, SBT and educational fields.

APPENDIX A: UNIVERSITY OF CENTRAL FLORIDA INSTITUTIONAL  
REVIEW BOARD LETTER



University of Central Florida Institutional Review Board  
Office of Research & Commercialization  
12201 Research Parkway, Suite 501  
Orlando, Florida 32826-3246  
Telephone: 407-823-2901 or 407-882-2276  
[www.research.ucf.edu/compliance/irb.html](http://www.research.ucf.edu/compliance/irb.html)

### Approval of Human Research

From: UCF Institutional Review Board #1  
FWA00000351, IRB00001138

To: Robert Dunn

Date: September 10, 2014

Dear Researcher:

On 9/10/2014 the IRB approved the following human participant research until 9/9/2015 inclusive:

Type of Review: Submission Correction for UCF Initial Review Submission Form  
Expedited Review Category # 6 & 7  
*This approval includes a Waiver of Written Documentation of Consent*  
Project Title: Objectively Defining Scenario Complexity: Towards Automated, Adaptive Scenario-Based Training  
Investigator: Robert Dunn  
IRB Number: SBE-14-10532  
Funding Agency: Marine Corps  
Grant Title: N/A  
Research ID: N/A

The scientific merit of the research was considered during the IRB review. The Continuing Review Application must be submitted 30 days prior to the expiration date for studies that were previously expedited, and 60 days prior to the expiration date for research that was previously reviewed at a convened meeting. Do not make changes to the study (i.e., protocol, methodology, consent form, personnel, site, etc.) before obtaining IRB approval. A Modification Form cannot be used to extend the approval period of a study. All forms may be completed and submitted online at <https://iris.research.ucf.edu>.

If continuing review approval is not granted before the expiration date of 9/9/2015, approval of this research expires on that date. When you have completed your research, please submit a Study Closure request in iRIS so that IRB records will be accurate.

Use of the approved, stamped consent document(s) is required. The new form supersedes all previous versions, which are now invalid for further use. Only approved investigators (or other approved key study personnel) may solicit consent for research participation. Participants or their representatives must receive a copy of the consent form(s).

All data, including signed consent forms if applicable, must be retained and secured per protocol for a minimum of five years (six if HIPAA applies) past the completion of this research. Any links to the identification of participants should be maintained and secured per protocol. Additional requirements may be imposed by your funding agency, your department, or other entities. Access to data is limited to authorized individuals listed as key study personnel.

In the conduct of this research, you are responsible to follow the requirements of the Investigator Manual.

On behalf of Sophia Dziegielewski, Ph.D., L.C.S.W., UCF IRB Chair, this letter is signed by:

  
IRB Coordinator

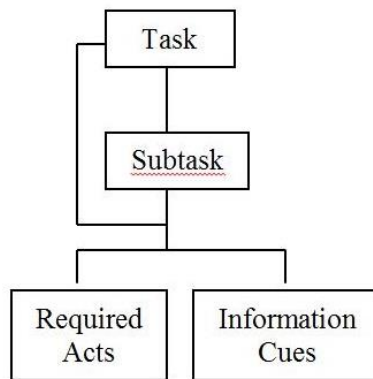
Page 2 of 2

## APPENDIX B: SCENARIO COMPLEXITY OVERVIEW AND CHEAT SHEET

A training scenario is presented to trainees who work their way through the situations to achieve the desired knowledge, skills and abilities. Some scenarios are very difficult and some are very simple. Currently, M1A1 AGTS gunnery training scenarios are presented in a matrix determined by subjective evaluation of complexity. However, to assist instructor/operators choose the appropriate level of scenario each scenario presented in the matrix should be determined by objective calculation of the scenario characteristics. In this way, novice trainees progress through intermediate and expert level scenarios efficiently and effectively.

A scenario has four characteristics: task complexity, task coordination, task framework and distractors.

The first characteristic **task complexity** is made up of three sub-characteristics: subtasks, required acts, and information cues.



### Definition of Variables

A *subtask* is a task necessary to perform the main task. If no subtask is necessary a task could stand alone. Both task and subtask must have a clear duration, a desired outcome or objective, and measures of performance.

Thinking of issuing a fire command write down some subtasks add any that are mentioned by other IOs below.

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A *required act* is different from other acts and is necessary for the successful completion of the task or subtask. For example, consider the task of moving your tank to an alternative battle position. For the driver navigation and steering subtasks are involved in this task. The navigation

subtask requires the act of observing the terrain; the subtask of steering requires the act of turning the driver's wheel.

Thinking of driving to an alternative Battle Position (BP) write down other required acts and add any others mentioned below.

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An *information cue* is information that must be monitored and processed in order to complete the task/subtask. For the gunner, the task of identifying a target includes the subtask of scanning; this subtask requires the trainee to monitor both right and left lateral limits. **ONLY necessary** cues are valid cues. For instance, in the example of the alternative BP, an additional information cue may be the TCo providing directions. However, if the input from the TCo is not necessary, then it could be considered a distraction.

Thinking of firing write down some information cues necessary for the gunner and add any others mentioned below.

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**Task Coordination** accounts for coordinating subtasks and required acts necessary for task completion. Moving to an alternative BP, the subtasks of steering and navigation are coordinated; the successful completion of steering (subtask-A) requires the successful completion of navigation (subtask-B) *and* completion of subtask-B requires the completion of subtask-A.

Thinking of the TC write down some task coordination required during gunnery and add any others mentioned below.

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The second characteristic **task framework** depends on whether a task is well- or poorly-defined by determining the number of task paths and task outcomes. Task framework accounts for the relation between task paths and the outcome associated with each, and addresses which outcomes are possible in a given task by considering four characteristics: task path, task outcome, conflicting outcomes and unknown outcomes.

**Task path** is the number of ways to arrive at the objective depending on the existing conditions. In the case of gunnery, having several ways to reach the objective increases the complexity of a task because efficiency matters. Yeah, you *could* engage a KA-52 with SABOT but if you miss, you may have a very bad day. An MPAT-A has a better chance. Two paths to consider but due to efficiency and effectiveness one path must be chosen.

How many task paths are there to killing an RPG team beyond 1200 meters?

**Task outcome** is defined as a measurement that must be satisfied in order to reach the desired objective. Example: In gunnery training targets must be engaged in order of lethality.

What other gunnery task outcomes can you think of?

**Conflicting outcomes** is when achievement of one objective can conflict with achieving another. Moving to an alternative BP may include the objective of getting there quickly versus the objective of staying alive by getting there without presenting silhouette flank to closing HIND-D.

Do you remember any times when you experienced conflicting outcomes?

**Unknown outcomes** account for the increase in mental processing as a result of not knowing whether certain paths will lead to certain outcomes. For example; the mental processing you went through at the mention of the last example, can I get there fast enough, can Close Air Support distract etc ... what you are doing is spending time choosing a path that meets the objective by evaluating the chance that each path will allow for success given the existing conditions.

The last characteristic, **distractors**, addresses the degree of stress and distraction the trainee may feel. Distractors are external factors that increase mental processing and/or reduce mental resources for the task. Distractors may cause less complex tasks to appear more complex.



For example, driving a tank to a CP in daylight, unlimited is a less complex task than driving at night with thermal sight malfunction.

Be careful to take into account the difference between an external factor and a subtask. The task of driving to a CP is moderated by deep mud or heavy traffic, but talking on CVC for order clarification during this task would be considered a subtask and not a distractor.

### Calculating Scenario Complexity

A scenario has four characteristics: task complexity, task coordination, task framework and distractors.

Task Complexity is the sum of its variables: subtasks, required acts, and information cues.

**Step 1.1:** A scenario may ask the trainee to perform subtasks to successfully complete the training task. The first step in calculating scenario complexity is determining the number of *subtasks* (if any).

A subtask has a unique desired outcome with measures of performance. The subtasks of navigation and steering are involved in the task of driving to an alternative BP.

**Step 1.1.1:** The second step in calculating scenario complexity is determining the number of *required acts* in each subtask.

A required act has (1) purpose or direction and is (2) different from other acts. The task of driving involves the subtask of navigation which may require the act of observing the terrain, the subtask of steering requires the act of turning the wheel. However, each act of observing the terrain or steering does NOT count as a different act.

**Step 1.1.2:** The third step to calculating complexity is to determine the number of *information cues* in each subtask.

Most subtasks require information to be monitored. The task of killing a target requires the subtask of lasing and this requires two sources of information to be monitored: the LRF and the motion of the target. Why the motion? Stationary or moving will dictate to dump or not to dump.

To review: To determine the value of component complexity the sum of its variables: subtasks, required acts, and information cues must be identified.

**Task Coordination** is the number of subtasks and required acts that are interdependent.

**Step 2.1:** The fourth step in calculating complexity is determining the level of *coordination complexity*. That is, a scenario **may** have a number of subtasks and required acts that are interdependent.

Some subtasks and required acts may depend on the successful completion of others and vice versa. In the example of driving, the subtasks of steering and observation are interdependent. That is, these subtasks are integrated and involve synchronization of activities to achieve the objective.

To review: To determine the value of task coordination the sum of interdependent subtasks must be identified.

**Task Framework** determines whether a task is well- or poorly-defined by determining the number and relation of paths to their outcomes. There are four variables within task framework: task path, task outcome, conflicting outcomes and unknown outcomes.

**Step 3.1:** To calculate task framework complexity first total the number of *task paths*.

The number of task paths is the number of ways to arrive at the objective depending on the existing conditions. When engaging two Type 98s there may be more than one path to take to achieve the task objective of killing both targets. Range and mobility are some existing conditions which **may** affect the number of paths.

**Step 3.2:** Second, to calculate framework complexity, determine the number of *task outcomes*.

Task outcomes measure performance and are aligned to the training objective. Every task has at least one outcome. In gunnery, some performance measures are time to ID and target classification.

**Step 3.3:** To calculate framework complexity, determine the number of *conflicting outcomes*.

Sometimes outcomes conflict with other outcomes. One outcome may be time to kill and another reticle aim. In this case, one outcome conflicts with the other if time is running out.

**Step 3.4:** Finally, to calculate framework complexity, determine the number of possible paths which do not lead to desired outcomes.

Some task paths may or may not lead to desired outcomes. If driving to alternative BP and there is only **one** path to get there the subtask of navigation is well-defined. If there are several paths and **some** paths lead to the BP and others do not that subtask is badly-defined. If there are several paths but **all** lead to the destination that subtask is somewhere in between.

## Distractors

**Step 4.1:** To calculate the final characteristic the number and level of distractors needs to be determined.

To calculate the number and level of distractors that increase mental processing or reduce mental resources. For example, driving a tank to a CP in daylight, unlimited is a less complex task than driving at night with thermal sight malfunction.

## REFERENCES

- Aldrich, C. (2004). Simulations and the future of learning: An innovative (and perhaps revolutionary) approach to e-learning. San Francisco, CA: Pfeiffer.
- Baker, D., Day, R., & Salas, E. (2006). Teamwork as an essential component of high-reliability organizations. *Health Services Research, 41*, 1576-1598.
- Barrows, H. S. (1985). How to design a problem based curriculum for the preclinical years. New York, NY: Springer Publishing Co.
- Benson, B. K. (1997). Scaffolding (coming to terms). *English Journal, 86*, 126-27.
- Billings, C. E. (1991). Human-centered aircraft automation philosophy: A concept and guidelines. Moffett Field, CA: NASA Technical Memorandum No. 103885.
- Billings, C. E., & Woods, D. D. (1994). Concerns about adaptive automation in aviation systems. *Human performance in automated systems: Current research and trends*, 264-269.
- Blake, M., & Butcher-Green, J. D. (2009). Agent-customized training for human learning performance enhancement. *Computers & Education, 53*, 966-976.
- Bolton, A. E. (2006). Immediate versus delayed feedback in simulation based training: matching feedback delivery timing to the cognitive demands of the training exercise. Dissertation. University of Central Florida. Orlando, FL.
- Bornstein, M. H., & Lamb, M. E. (1999). *Developmental psychology: An advanced textbook*. Mahwah, NJ: L. Erlbaum Associates.
- Borthick, A., Jones, D. R., & Wakai, S. (2003). Designing learning experiences within learners' zones of proximal development (ZPDs): Enabling collaborative learning on-site and online. *Journal of Information Systems, 1*, 107-134.
- Bremner, M., Aduddell, K., Bennett, D., & Van Geest, J. (2006). The use of human patient simulators: Best practices with novice nursing students. *Nurse Educator, 31*, 170-174.
- Brennan, R. L. (1992). An NCME instructional module on generalizability theory. *Educational Measurement: Issues and Practice, 11*, 27-34.
- Brusilovsky, P., & Miller, P. (2001). Course delivery systems for the virtual university. In F. T. Tschang & T. Della Senta (Eds.), *Access to knowledge: New information technologies and the emergence of the virtual university* (pp. 167-206). Amsterdam: Elsevier Science and International Association of Universities.

- Burgos, D., Tattersall, C., & Koper, R. (2007). How to represent adaptation in e-learning with IMS learning design. *Interactive Learning Environments*, 15, 161-170.  
doi:10.1080/10494820701343736
- Campbell, D. J. (1988). Task complexity: A review and analysis. *Academy of Management Review*, 13, 40-52.
- Campbell, D. (1991). Goal levels, complex tasks, and strategy development: A review and analysis. *Human Performance*, 4, 1-31.
- Cannon-Bowers, J. A., & Salas, E. (1998). Individual and team decision making under stress: Theoretical underpinnings. In J. A. Cannon-Bowers, & E. Salas, (Eds.), *Making Decisions Under Stress: Implications for Individual and Team Training* (pp. 17-38). Washington, DC: APA Press.
- Chak, A. (2001). Adult sensitivity to children's learning in the zone of proximal development. *Journal for the Theory of Social Behaviour*, 31, 383-395.
- Chi, M., & VanLehn, K. (2010). Meta-cognitive strategy instruction in intelligent tutoring systems: How, when, and why. *Educational Technology & Society*, 13, 25-39.
- Chin J., Dukes R., & Gamson, W. (2009) Assessment in simulation and gaming: A review of the last 40 years. *Simulation & Gaming*, 40, 553-568.
- Choi, J. I., & Hannafin, M. (1995). Situated cognition and learning environments: Roles, structures, and implications for design. *Educational Technology Research and Development*, 43, 53-69.
- Chomsky, N. (1973). *For reasons of state*. Pantheon bks.
- Clements, D. H., & Battista, M. T. (1992). Geometry and spatial reasoning. In D. A. Grouws (Ed.), *Handbook of research on mathematics teaching and learning* (pp. 420-464). New York, NY: Macmillan.
- Collins, A., Brown, J. S., & Holum, A. (1991). Cognitive apprenticeship: Making thinking visible. *American Educator*, Winter, 38-46.
- Cronbach, L. J., Nageswari, R., & Gleser, G. C. (1963). Theory of generalizability: A liberation of reliability theory. *The British Journal of Statistical Psychology*, 16, 137-163.
- Cronbach, L. J., & Snow, R. E. (1977). Aptitudes and instructional methods: A handbook for research on interactions. New York, NY: Irvington.

- De Bra, P., Aroyo, L., & Cristea, A. (2004). Adaptive web-based educational hypermedia. In M. Levene & A. Poullovassilis (Eds.), *Web dynamics, adaptive to change in content, size, topology and use* (pp. 387-410). Berlin: Springer Verlag.
- De Bra, P., Stash, N., & Smits, D. (2005). Creating adaptive web-based applications. Paper presented at the 10th International Conference on User Modeling, Edinburgh.
- Dewey, J. (1891). Processes of knowledge. In (3rd rev. ed.) *Psychology* (pp. 81-155). American Book Company.
- Dewey, J. (1913). *Interest and effort in education*. Boston, MA: Riverside Press.
- Dewey, J. (1938). *Experience and education*. New York, NY: Macmillan.
- Dick, W., Carey, L., & Carey, J. O. (2009). *The systematic design of instruction*. Upper Saddle River, NJ: Merrill/Pearson.
- Directorate of Training and Doctrine, Maneuver Center of Excellence. Presentation to PM TRASYS, August 13, 2013. Fort Benning, GA.
- Dunn, W. E. & Lantolf, J. P. (1998). Vygotsky's zone of proximal development and Krashen's 1+1: Incommensurable constructs; incommensurable theories. *Language Learning*, 48, 411-442.
- Dunne, R., Schatz, S., Fiore, S., Martin, G., & Nicholson, D. (2010). Scenario-based training: Scenario complexity. Proceedings of the 54th Annual Conference of the Human Factors and Ergonomics Society. San Francisco, CA.
- Dunne, R., Schatz, S., Fiore, S., Nicholson, D., & Fowlkes, J. (2010). Optimizing decision preparedness by adapting scenario complexity and automating scenario generation. Proceedings of the ModSim International World Expo 2010, Hampton, VA.  
[http://ntrs.nasa.gov/archive/nasa/casi.ntrs.nasa.gov/20110012060\\_2011012533.pdf](http://ntrs.nasa.gov/archive/nasa/casi.ntrs.nasa.gov/20110012060_2011012533.pdf).
- Eun, B., Knotek, S., & Heining-Boynton, A. (2008). Reconceptualizing the zone of proximal development: The importance of the third voice. *Educational Psychology Review*, 20, 133-147.
- Evensen, L. S. (2007). 'With a little help from my friends'? Theory of learning in applied linguistics and SLA. *Journal of Applied Linguistics*, 4, 333-353.
- Frese, M. (1989). Theoretical models of control and health. In S. L. Sauter, J. J. Hurrell, & C. L. Cooper (Eds.), *Job Control and Worker Health* (pp. 107-128). Chichester, UK: Wiley.

- Fuson, K. C. (1997). Research-based mathematics curricula: New educational goals require programs of four interacting levels of research. *Issues in Education*, 3, 67-79.
- George, D., & Mallery, P. (2003). *SPSS for Windows step by step: A simple guide and reference. 11.0 update*. Boston, MA: Allyn & Bacon.
- Good, M. (2003). Patient simulation for training basic and advanced clinical skills. *Medical Education*, 37, 14-21.
- Grabinger, R. S. (1996). Rich environments for active learning. In D. H. Jonassen (Ed.), *Handbook of research for educational communications and technology* (pp. 665-692). New York, NY: Macmillan.
- Hartley, J. R. (1973). The design and evaluation of an adaptive teaching system. *International Journal of Man-Machine Studies*, 5, 421-436.
- Herrington, J., & Oliver, R. (2000). An instructional design framework for authentic learning environments. *Educational Technology Research and Development*, 48, 23-48.
- Hogan, K., & Pressley, M. (Eds.). (1997). *Scaffolding student learning: Instructional approaches and issues*. Cambridge, MA: Brookline.
- Iverson, K., & Colkey, D. (2004). Scenario-based e-learning design. *Performance Improvement*, 43, 16-22.
- Jodlowski, M. T. (2008). Extending long term working memory theory to dynamic domains: The nature of retrieval structures in situation awareness. Dissertation. Mississippi State University. Starkville, Mississippi.
- Jonassen, D. H., Tessmer, M., & Hannum, W. H. (1999). *Task analysis methods for instructional design*. Mahwah, NJ: Lawrence Erlbaum Associates.
- Keeping Pace. (2009). <http://www.kurzweilai.net/articles/art0134.html?printable=1>
- Kenny, C. (2006). Automated tutoring for a database skills training environment. Unpublished master's thesis, Dublin City University, Ireland.
- Kenny, C., & Pahl, C. (2009). Intelligent and adaptive tutoring for active learning and training environments. *Interactive Learning Environments*, 17, 181-195.
- Kindley, R. (2002). The power of simulation-based e-Learning (SIMBEL). *The Elearning Developers Journal. The Elearning Guild*, 17, 1-8.

- Kinshuk, Patel, A., & Scott, B. (2001). Intelligent tutoring: From SAKI to Byzantium. *Kybernetes*, 30, 807-818.
- Klann, M. (2003). The EUD-net's roadmap to end-user development. Paper presented at the Workshop on End User Development at ACM CHI 2003 Conference, Fort Lauderdale, FL.
- Klein, G. A. (1989). Recognition-primed decisions. In W. B. Rouse (Ed.), *Advances in Man-Machine Systems Research*, v. 5 (pp. 47-92). Greenwich, CT: JAI Press.
- Kohn, M. L., & Schooler, C. (1978). The reciprocal effects of the substantive complexity of work and intellectual flexibility: A longitudinal assessment. *American Journal of Sociology*, 84, 24-52.
- Krashen, S. D. (1982). Principles and practice in second language acquisition. Oxford: Pergamon.
- Krashen, S. D. (1985). The input hypothesis: Issues and implications. London: Longman.
- Kurlik, A. (1993). Modeling strategic behavior in human-automation interaction: Why 'aid' can (and should) go unused. *Human Factors*, 35, 221-242.
- Kurzweil, R. (2001). The law of accelerating returns. <http://www.kurzweilai.net/the-law-of-accelerating-returns>
- Landauer, T. K. (1995). *The trouble with computers*. Cambridge, MA: MIT Press.
- Lantolf, J. P. (2008). SLA, i+1, SCT, the ZPD, and other things: A response to Evensen. *Journal of Applied Linguistics*, 5.2, 215-219.
- Link. (2009). <http://www.link.com/history.html>
- Livingston, S., Fennessey, G., Coleman, J., Edwards, K., & Kidder, S. (1973). The Hopkins games program: Final report on seven years of research (Report no. 155). Baltimore, MD: Johns Hopkins University Center for Social Organization of Schools.
- Lockheed Martin Corporation. (2012). Training system utilization handbook, volume 1. M1A1 firepower enhancement program (FEP). Advanced gunnery training system (AGTS) for the USMC combat vehicle training system (CVTS) devices 17B24 and 17B25. Orlando, FL: Lockheed Martin.
- Louis, G. W. (2009). Using Glasser's choice theory to understand Vygotsky. *International Journal of Reality Therapy*, 29, 20-23.



- Lum, H., Fiore, S. M., Rosen, M. R., & Salas, E., (2008). Complexity in collaboration: Developing an understanding of macrocognition in teams through examination of task complexity. *Proceedings of 52<sup>nd</sup> Annual Meeting of the Human Factors and Ergonomics Society*, New York, NY., 1425-1429.
- Malin, J. T. & Schreckenghost, D. L. (1992). Making intelligent systems team players: Overview for designers. NASA Technical Memorandum 104751. Houston, TX: Johnson Space Center.
- Martin, G., Schatz, S., Bowers, C. A., Hughes, C. E., Fowlkes, J., & Nicholson, D. (2009). Automatic scenario generation through procedural modeling for scenario-based training. *Proceedings of the 53rd Annual Conference of the Human Factors and Ergonomics Society*. Santa Monica, CA., 1949-1953.
- McMichael, A. (2007). PC games and the teaching of history. *History Teacher*, 40, 203-218.
- Melis, E., & Ullrich, C. (2003). Local and global feedback. In *Proceedings of AIED 2003*, 11<sup>th</sup> International Conference in Artificial Intelligence in Education, Sydney, Australia (476-478). Amsterdam: IOS Press.
- Merrill, M. (2007). A task-centered instructional strategy. *Journal of Research on Technology in Education*, 40, 5-22.
- Myerson, R. B. (1991). *Game Theory: Analysis of Conflict*. Harvard University Press.
- Nardi, B., (Ed.). (1997). Educational context and consciousness: Activity theory and human computer interaction. Cambridge, MA: MIT Press.
- National Aeronautics and Space Administration. (1963). Astronautical and aeronautical events of 1962: Report of the National Aeronautics and Space Administration committee on science and astronautics. Presented to the U.S House of Representatives to the 88<sup>th</sup> Congress, First session.
- Nunnally, J. C. (1978). *Psychometric Theory*. New York: McGraw Hill.
- Oblinger, D. (2003). Boomers, gen-Xers, and millennials: Understanding the "new students." *EDUCAUSE Review*, 38, 36-45.
- Oblinger, D. (2004). The next generation of educational engagement. *Journal of Interactive Media in Education*, 8, 1-18.
- Oeser, O., & O'Brien, G. (1967). A mathematical model for structural role theory: III. *Human Relations*, 20, 83-97.

- Parasuraman, R. (2003). Neuroergonomics: Research and practice. *Theoretical Issues in Ergonomics Science*, 4, 5-20.
- Parasuraman, R., Mouloua, M., Molloy, R. & Hilburn, B. (1996). Monitoring of automated systems. In R. Parasuraman and M. Mouloua (Eds.), *Automation and human performance: Theory and applications* (pp. 91-115). Mahwah, NJ: Lawrence Erlbaum Associates.
- Parasuraman, R., & Riley, V. (1997). Humans and automation: Use, misuse, disuse, abuse. *Human Factors*, 39, 230-253.
- Parasuramn, R., Sheridan, T. B., & Wickens, C. D. (2000). A model for types and levels of human interaction with automation. *IEEE Transactions on Systems, Man, and Cybernetics – Part A: Systems and Humans*, 30.
- Parker, C. & Myrick, F. (2009). A critical examination of high-fidelity human patient simulation with the context of nursing pedagogy. *Nurse Education Today*, 29, 322-329.
- Pfeiffer, J. W., & Jones, J. E. (1975) Introduction to the structured experiences section. In J. E. Jones & J. W. Pfeiffer (Eds.), *The 1975 annual handbook for group facilitators*. La Jolla, CA: University Associates.
- Prensky, M., (2001). *Digital game-based learning*. New York, NY: McGraw-Hill.
- Program Manager Training System. (2014a). United States Marine Corps training effectiveness evaluation for combat vehicle training system (CVTS) M1A1 advanced gunnery training system (AGTS). Orlando, FL: Program Manager Training System.
- Program Manager Training System. (2014b). Marine Corps verification & validation (V&V) report for the combat vehicle training system (CVTS) M1A1 advanced gunnery training system (AGTS): Relocatable (RAGTS), modile (MAGTS), deployable (DAGTS) and tabletop (TAGTS) configurations. Orlando, FL: Program Manager Training System.
- Quintana, C., Krajcik, J., & Soloway, E. (2001). Issues and methods for evaluating learner-centered scaffolding. In *IEEE international conference on advanced learning technologies (ICALT 2001)* 353-356.
- Reder, L. M., & Schunn, C. D. (1999). Bringing together the psychometric and strategy worlds: Predicting adaptivity in a dynamic task. In D. Gopher & A. Koriath (Eds.), *Attention and performance XVII: Cognitive regulation of performance: Interaction of theory and application* (pp. 315-337). Cambridge, MA: MIT Press.
- Reigeluth, C. M. (1983). The elaboration theory of instruction. In C. M. Reigeluth (Ed.), *Instructional design theories and models: An overview of their current status* (pp. 335-381). Hillsdale, NJ: Lawrence Erlbaum Associates, Inc.

- Reigeluth, C. M. (Ed.). (1999). Instructional design theories and models: A new paradigm of instructional theory (Vol. II). Mahwah, NJ: Lawrence Erlbaum Associates.
- Reigeluth, C. M., & Rogers, C. A. (1980). The elaboration theory of instruction: Prescriptions for task analysis and design. *NSPI Journal*, 19, 16-26.
- Reiser, R. A. (2001). A history of instructional design and technology: Part I: A history of instructional media. *Educational Technology Research & Development*, 49, 53-64.
- Robinson, P. (2003). The cognition hypothesis, task design, and adult task-based language learning. *Second Language Studies*, 21, 45-105.
- Sarter, N. B. and Woods, D. D. (1995). How in the world did we ever get into that mode? Mode errors and awareness in supervisory control. *Human Factors*, 37, 5-19.
- Savery, J. R. & Duffy, T. M. (1995). Problem-based learning: An instructional model and its constructivist framework. *Educational Technology* 35, 31-38.
- Scerbo, M. W. (1996). Theoretical perspectives on adaptive automation. In R. Parasuraman and M. Mouloua (Eds.), *Automation and human performance: Theory and applications* (pp. 37-63). Mahwah, NJ: Lawrence Erlbaum Associates.
- Scerbo, M. W., Freeman, F. G., & Mikulka, P. J. (2003). A brain-based system for adaptive automation. *Theoretical Issues in Ergonomics Science*, 4, 200.
- Schinke-Llano, L. (1993). On the value of a Vygotskian framework for SLA theory and research. *Language Learning*, 43, 121-129.
- Sheridan, T.B. (1987). Supervisory control. In G. Salvendy (Ed.), *Handbook of Human Factors* (pp. 1243-1268). New York, NY: Wiley.
- Sheridan, T. B., & Verplank, W. L. (1978). Human and computer control of undersea teleoperators. MIT Man-Machine Systems Laboratory, Cambridge, MA: Tech Rep.
- Schraagen, J. M., Chipman, S. F., & Shute, V. J. (2000). State-of-the-art review of cognitive task analysis techniques. In J. M. Schraagen, S. F. Chipman & V. J. Shute (Eds.), *Cognitive Task Analysis* (pp. 467-487). Mahwah, NJ: L. Erlbaum Associates.
- Skehan, P., & Foster, P. (2001). Cognition and tasks. *Cognition and second language instruction*, 183-205.

- Smith, C., Gillham, D., McCutcheon, H., & Ziaian, T. (2011). Scenariation: Scenario generation for online teaching in nursing and health sciences. *British Journal Of Educational Technology*, 42, 962-972.
- Tennyson, R. D. (1980). Advisement and management strategies as design variables in computer-assisted instruction.
- Ullrich, C., & Melis, E. (2010). Complex course generation adapted to pedagogical scenarios and its evaluation. *Educational Technology & Society*, 13, 102-115.
- United States Department of the Army. (1996). A leader's guide to lane training. TC 25-10. Washington, DC: U.S. Department of the Army.
- United States Department of Education. (2001). No child left behind (Public Law 107–110). Washington, DC: Intergovernmental relations.
- United States Department of Education. (2005). The national educational technology plan. Washington, DC: U.S. Department of Education.
- United States Marine Corps. (1996). Marine Corps Reference Publication (MCRP) 3-0A. Unit Training Management Guide. Washington, DC: Department of the Navy.
- United States Marine Corps. (2009). Field Manual 3-20.21/ MCWP 3-12.2. Heavy Brigade Combat Team (HBCT) Gunnery. Washington, DC: Department of the Navy.
- United States Marine Corps. (2000). Field Manual 17-12-7. Tank Gunnery Training Devices and Usage Strategies. Washington, DC: Department of the Navy.
- United States Marine Corps. (2011). The Tank Training and Readiness (T&R) Manual, NAVMC 3500.1A. Washington, DC: Department of the Navy.
- United States Marine Corps. (2012). TC 3-20.1. Direct Fire Gunnery (Ground), Final Draft. 15 Nov 2012. Washington, DC: Department of the Navy.
- United States Marine Corps. (2013). The Tank Training and Readiness (T&R) Manual, NAVMC 3500.121. Washington, DC: Department of the Navy.
- Van Der Stuyf, R. R. (2005). Scaffolding as a teaching strategy. Accessed on 2009, <<http://condor.admin.ccny.cuny.edu/group4/>>.
- Vandergriff, D. E., Maj. (2003). Lessons learned with decision making. Unpublished After Action Review, Washington, DC: Georgetown University Army ROTC.

- von Seggern, D. (2007). *Standard Curves and Surfaces with Mathematics*. Boca Raton, FL: CRC Press
- Vygotsky, L. S. (1978). *Mind in society: The development of higher psychological processes*. Cambridge, MA: Harvard University Press.
- Wang, Y., Tseng, M., & Liao, H. (2009). Data mining for adaptive learning sequence in English language instruction. *Expert Systems with Applications*, 36, 7681-7686.  
doi:10.1016/j.eswa.2008.09.008.
- Wickens, C. D., Mavor, A. S., McGee, J., & United States National Research Council. (1997). *Flight to the Future: Human Factors in Air Traffic Control*. Washington, D.C: National Academy Press.
- Wiener, E. L. (1988). Cockpit automation. In E. L. Wiener and S. C. Nagel, (Eds.), *Human Factors in Aviation* (pp. 433-461) New York, NY: Academic.
- Wiener, E. L. (1989). Human factors of advanced technology ('glass cockpit') transport aircraft, Technical report 117528. Moffett Field, CA: NASA Ames Research Center.
- Wiener, E. L. & Curry, R. E. (1980). Flight-deck automation: Promises and problems. *Ergonomics*, 23, 995-1011.
- Wood, D., Bruner, J. S., & Ross, G. (1976). The role of tutoring in problem solving. *Journal of Psychology and Psychiatry*, 17, 89-100.
- Woods, D. D. (1994). Automation: apparent simplicity, real complexity. In M. Mouloua & R. Parasuraman (Eds.), *Human performance in automated systems: Current research and trends* (pp. 1-7) Hillsdale, NJ: Lawrence Erlbaum Associates.
- Woods, D. D. (1996). Decomposing automation: apparent simplicity, real complexity. In R. Parasuraman & M. Mouloua (Eds.), *Automation and human performance: Theory and applications* (pp. 3-17) Mahwah, NJ: Lawrence Erlbaum Associates.
- Zook, A., Lee-Urban, S., Riedl, M. O., Holden, H. K., Sottolare, R. A., & Brawner, K. W. (2012, May). Automated scenario generation: Toward tailored and optimized military training in virtual environments. In *Proceedings of the International Conference on the Foundations of Digital Games* (pp. 164-171). ACM.