Developing Accelerated Learning Models in GIFT for Medical Military and Civilian Training

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Abstract. This paper will discuss the protocol of an inter-institutional study between the Army Research Laboratory (ARL) and Columbia University Medical Center that seeks to identify pedagogical models that can be employed in the Generalized Intelligent Framework for Tutoring system (GIFT) to support the transfer of skills from training to operations in individual Soldiers within the domain of critical care, addressing topics in hemorrhage, airway compromise, and/or tension Pneumothorax. The scientific approach will include two studies. The first correlational study aims to examine the effect of human variability on learning, performance, retention, and transfer by using individual differences (e.g., personality traits, cognitive abilities, and motivation) as criteria to tailor individual training for Soldier learning needs. The second study will be an experiment to examine how the priming of analogical reasoning tasks effects the problem-solving outcomes of increasingly complex critical care case study content. The authors intend to incorporate the findings of these two studies to support the development of accelerating expert-level reasoning skills and strategies to achieve cognitive flexibility, one of two paths that has been identified as a way to accelerate proficiency.

Keywords: GIFT · Medical education · Accelerated learning

1 Introduction

1.1 Overview

Developing accelerated learning models in the Generalized Intelligent Framework for Tutoring (GIFT) [26] for medical military and civilian training is a two-phase, inter-institutional effort between the Army Research Laboratory, Columbia University Medical Center, the University of Wisconsin, and the United States Military Academy. The overarching objective is to explore how to support accelerated learning within the domain of critical medical care for Soldiers and civilians as delivered by GIFT.

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1.2 Background

This two-study effort seeks to address ARL's Essential Research Area: Accelerated Learning for a Ready and Responsive Force, and contribute to an understanding of what factors, tools, and methods help individual Soldiers learn faster, perform at consistently higher levels, retain knowledge and skills longer, and transfer skills from training to operations at a higher rate. This effort will also address the gap of identifying pedagogical models that can be employed in GIFT to support the transfer of skills from training to operations in individual Soldiers within the domain of critical care, addressing topics in hemorrhage, airway compromise, and/or tension pneumothorax – three leading causes of battlefield deaths [16].

GIFT is a service-oriented framework of tools, methods and standards to author, manage, and assess computer-based tutoring instruction [26]. GIFT is being developed under the Adaptive Training Research Program at the Learning in Intelligent Tutoring Environments (LITE) Laboratory, part of the U.S. Army Research Laboratory - Human Research and Engineering Directorate (ARL-HRED). The goal of this inter-institutional project is to provide empirical findings to U.S. Army stakeholders to contribute to developing models for GIFT to support an accelerated learning pathway for expert-level medical education, as well as explore models that support the higher-order thinking processes of learners [8]. As noted in Hoffman et al. [8], to accelerate instruction requires not only an understanding of tasks that need be learned, but also an understanding of the learner and a delivery of instruction that optimizes the growth and development of expertise by the learner. Lastly, by expanding our participant pool to civilians, we seek to improve the generalizability of these findings and improve external validity, making this study relevant not only to U.S. Army stakeholders, but to civilian medical education institutions as well.

2 Theoretical Approach

2.1 Accelerated Learning

Within the field of accelerated learning, there has been a distinction made between efforts for accelerated learning for novices and accelerated learning that target the journeyman, or senior apprentice, on their way to an expert level [7, 12, 14]. Hoffman [7] identifies the basic proficiency categories of learners as follows:

Naïve: One who is ignorant of a domain.
Novice: Someone who is new – a probationary member who has had some "minimal" exposure to the domain.
Initiate: Someone who has been through an initiation ceremony – a novice who has begun introductory instruction.
Apprentice: One who is learning, a student undergoing a program of instruction beyond the introductory level. Traditionally one who is immersed in the domain by living with and assisting someone at a higher level.

Journeyman: A person who can perform a day's labor unsupervised, although under working orders. An experienced and reliable work who has achieved a level of competence.

Expert: The distinguished or brilliant journeyman, whose judgments are un-commonly accurate and reliable, whose performance shows consummate skill and economy of effort, who can deal effectively with certain types of rare or tough cases. Has extensive experience with subdomains.

Master: One who is a journeyman or expert qualified to teach those at a lower level. A member of an elite group of experts whose judgments establish regulations, standards, or ideals.

While novices are still in a process of synthesizing their understandings of a new domain, the journeyman/apprentice and expert are in process of utilizing those understandings [4, 10, 11]. This process has been called "cognitive readiness," which includes higher-order thinking competencies, such as reasoning skills, amongst others [15].

The cognitive readiness of experts includes not only training that involves mirroring cognitive tasks in real-world tasks, such as using case libraries and scenario-based learning [11] but more importantly it includes the development of a skill set that is used adaptively when facing associated problems or challenges [14]. Jung [14] identifies characteristics of experts that can be universally applied to all domains, which include:

- Possession of an extensive and highly organized domain knowledge.
- The capability of identifying the underlying structure of domain problems.
- Choosing and employing proper problem-solving skills and procedures for the problem at hand.

Essentially, in the effort of supporting expertise development, Jung [14] and Hoffman et al. [12] recommend fostering high-level reasoning skills. According to the Center for Advancement of Learning and Assessment [15], higher order thinking skills include critical, logical, reflective, metacognitive, and creative thinking, that are activated when individuals encounter unfamiliar problems, uncertainties, questions, or dilemmas. Within this framework, then, supporting an accelerated learning pathway to develop the cognitive skills of an expert can arguably be rooted in the development of creative thinking, specifically creative reasoning, which addresses a core element of cognitive readiness. Indeed, this approach falls well within recent thinking of education and training of Army personnel where creative thinking has been noted as both critical and necessary for successful leadership of the military [1].

2.2 Creative Thinking: Analogical Reasoning

Creative thinking includes the convergent process of identifying relevant items or schemas, and the divergent process of combining these items in novel ways [18]. Convergent thinking refers to deductive generation of a single, accurate, concrete, solution [24]. Divergent thinking, in contrast, requires the ability to create multiple, novel ideas [29]. Divergent thinking includes not only a freedom from functional fixedness [6] but it includes the ability to find different and original solutions to problems and tasks [21]. Importantly, Weisberg [29] has argued that problem solving includes both a level of content expertise in a specific domain as well as strong creative thinking skills, which includes analogical thinking.

Echoing Weisberg's [29] analysis, Weinberger et al. [28] research has focused on creative reasoning – specifically on examining analogical reasoning. Their argument extends the theoretical into the practical evidence of the value of analogical reasoning, noting it as the basis of innovation in science and industry. However, in order for divergent and creative thinking to solve actual problems, solutions must be generated within certain constraints where the outcomes are viable [20]. As such, Weinberger et al. [28], highlight the notion that analogical reasoning is a good model for creativity in reasoning because it involves not only divergent thinking, but more practically it involves the use of sensible constraints.

Therefore, supporting creative thinking is not merely the generation of original and elegant solutions [2], but solutions that are sensible and viable to address complex, novel, ill-defined or poorly structured problems [20]. Within this context, then, creative thinking in this two-phase project will be operationalized within the framework of creative reasoning as constrained for the purposes of producing socially valuable products, and measured by way of divergent thinking tests, specifically analogical thinking tasks [3, 5, 28]. While creative reasoning is typically assessed according to domain specific products, the objective of this current research project will lay the groundwork for whether an instructional design that primes analogical reasoning tasks with sequentially complex case studies can be used as an effective pedagogical model across different domains to support expert level problem solving.

Accordingly, to assess divergent thinking includes seeking out first order relations to form valuable second-order relations that produce innovative solutions, and involves the ability to generate different and original solutions to problems and tasks in a problem context [21, 31]. After having conducted a review of the literature, the previously validated Analogical Finding Task Matrix [28] has been identified as the instrument by which the authors will measure divergent thinking.

2.3 Creative Thinking: Mental Rotation Tasks

Another capacity that has identified as relevant to high-level creative problem solving, and particularly relevant for learning in anatomy that is relevant to critical medical care, is a person's spatial ability [23]. The ability to manipulate metal imagery has not only been identified as a key factor in problem solving, but in memory as well [30]. Spatial ability and mental rotation has also been linked to success in surgical skill acquisition [27]. Most pertinent to this project is a current research interest in determining whether mental rotation can be improved through training as one methodology to improving performance in STEM [23].

There is a robust body of literature in the field of mental rotation testing [22, 25] More recently, Ganis and Kievit [5], constructed and validated a new set of three-dimensional shapes for investigating mental rotation processes that improves on the work of Shepard and Metzler [25]. One such improvement is the inclusion of shading cues that minimize error due to crowding (meaning, difficulty distinguishing edges of objects) and depth ambiguity (meaning, ambiguity as to the direction of the object from the perspective of the viewer). The result of Ganis and Kievit's [5] work has resulted in a new set of 48 distinct mental rotations objects with rotated versions that include shading depth cues. Speed and accuracy are measured, then, to determine a person's level of spatial abilities. This metric will be particularly important to measure – not only to achieve a baseline assessment of a person's spatial abilities, but also will be informative as to the level of detailed imagery that will be narrated in the medical case study scenarios.

2.4 Creative Reasoning: Content Mastery

There is a body of research that maintains that another key element to creative thinking and reasoning is content mastery [13, 17, 29, 31]. The target domain for this project will be limited to medical education, specifically critical care, addressing topics in hemorrhage, airway compromise, and/or tension Pneumothorax, which are three leading causes of battlefield deaths. Focusing on these areas are in line with prior research [8, 9, 14, 19] that maintains accelerated learning methods should include leveraging computer technology to develop libraries, or case studies, that represent tough tasks and capture expert knowledge and skill. Ideally, future work in accelerated learning should include employing a library of "tough cases" that focus cognitive training on real work practice, highlighting the use of analogical strategies.

For this research, then, critical care case studies will be developed so that the successful completion of each case study, measured by way of an assessment instrument following each case study (still to be developed), will represent a different level of problem solving expertise from novice, to journeyman, to expert. Dr. R. Stanley Hum of Columbia Medical Center will develop these critical care case scenarios, and have these scenarios validated by critical care expert Dr. Michael Wilhelm of the University of Wisconsin's Medical Center, as well as by Major Angela Yarnell, Ph.D., of the United States Military Academy, whose expertise lies in medical education and includes critical care.

3 Experimental Designs of Study One and Two

3.1 Study One: Analogical Reasoning and Trait Correlational Study

For the first phase of this project, an initial correlational study will examine strengths of correlations between mental rotation/spatial ability; grit; analogical reasoning; personality types; and level of medical knowledge expertise. The goal is to determine what traits are relevant to superior analogical thinking skills and to use these outcomes to help inform the experimental design of study two. This information is key in designing an adaptive tutoring platform to tailor instruction for the individual medical military and civilian populations.

The first study will recruit approximately 128 participants through the United States Military Academy's (USMA) experiment sign up system (SONA-Systems) in collaboration with the Department of Behavioral Sciences and Leadership. Recruitment will also be conducted at Columbia Medical Center and Columbia University, seeking approximately 128 participants. This first study will be completed online as it consists of self-reporting questionnaires and surveys, and tasks that measure individual traits.

3.2 Study Two: Priming Analogical Reasoning Tasks and Problem Solving Medical Scenarios of Increasing Complexity

The second phase of this project will be a within-and between group design experiment. This experiment will examine how the priming of analogical reasoning tasks, and sequencing of the analogical reasoning with schematic content (medical definitions of related content), and scenario-based case studies of increasing complexity, effect the accuracy and speed of participants' problem-solving outcomes. This experiment will also examine how the other variables of personality type, grit, and level of medical knowledge expertise, moderate and mediate effects on the dependent variables of time and problem-solving outcomes of participants assigned to three experimental and one control condition groups.

Design. The design of this experiment will be a 3 $\times$ 1 experimental design with one control group and three experimental conditions. The intervention conditions (conditions one, two, and three, will prime the participant with one or both analogical reasoning task prior to reading the case studies and answering the post assessments of the case studies. All participants will be taking all the same instruments and only the manipulation of sequencing is different. The primary focus of this experiment will be to test the hypothesis that there will be a statistically significant difference between the learning outcomes in the experimental condition that primes participants with both mental rotation and analogical reasoning tasks when solving for the medical case studies – and the condition that primes only with the analogical reasoning task, the condition that primes only with the mental rotation task, and the control condition that does not prime analogical reasoning nor mental rotation tasks prior to solving the case studies.

Procedure. This second study will recruit 128 participants the United States Military Academy's (USMA) experiment sign up system (SONA-Systems) in collaboration with the Department of Behavioral Sciences and Leadership. Recruitment will also be conducted at Columbia University Medical Center, seeking approximately 40 participants. During the 1-h session with each participant, the participant will take, via the GIFT platform: a demographic survey, a pretest on critical care, a grit survey, a personality test, and an analogical reasoning task. Further all conditions will have post-tests after each case study that will assess their ability to successfully resolve the problems laid out in the case studies. Participants will be randomly assigned to one of four conditions on a critical care course (to be developed) that will be delivered via the GIFT platform, as follows:

1. *Experimental group one*: Sequence of mental rotation task, analogical reasoning, and schematics prior to scenario case studies, sequenced from novice to expert, post-test that evaluates problem solving of medical scenarios
2. *Experimental group two*: Sequence of analogical reasoning and schematic material prior to scenario case studies, sequenced from novice to expert; mental rotation task after post-test that evaluates problem solving of medical scenarios

3. *Experimental group three*: Sequence of mental rotation tasks and schematics prior to case studies of increasing complexity of novice to expert; analogical reasoning after post-test that evaluates problem solving of medical scenarios
4. *Control group*: Sequence only of schematics prior to case studies of increasing complexity from novice to expert; mental rotation and analogical reasoning after post-test that evaluates problem solving of medical scenarios.

The primary objective of this second study will be to test the hypothesis that there will be a statistically significant difference between the problem-solving outcomes in condition 1 vs. conditions 2 and 3 and the control condition. However, analyses will also be run to determine whether personality traits will function as a moderator and have an interactive effect on learning outcomes; to determine if Grit function as a mediator and has an interactive effect on problem solving outcomes; to examine whether analogical reasoning skill will function as a mediator and have an interactive effect on problem solving outcomes; and to see whether there will be a statistically significant difference in time of completion and accuracy of problem solving outcomes not only between conditions, but between novice and expert levels of medical students/practitioners.

4 Conclusion

In sum, the purpose of this inter-institutional study is aimed at developing a pedagogical model to support accelerated learning for the purposes of creating a learning pathway model that would accelerate the learning from journeyman to expert via GIFT. After determining what trait variables are more highly correlated to analogical reasoning and mental rotation, the authors will proceed to develop critical care case studies to further explore whether analogical reasoning and mental rotation tasks support expert critical care problem solving. We expect that in the second study will see a statistically significant effect for priming of analogical reasoning and mental rotation tasks in relationship to the fluency and speed of the problem-solving abilities of participants when solving the medical case studies, particularly as they increase in complexity. Further, we expect our post-analysis to provide evidence that can inform future examinations on how the engagement with analogical and creative reasoning tasks can be further capitalized upon to accelerate the learning process within the field of critical care medical education.

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