DIMENSIONS OF INSTRUCTIONAL MANAGEMENT RESEARCH IN SUPPORT OF A GENERALIZED INTELLIGENT FRAMEWORK FOR TUTORING (GIFT)

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ABSTRACT

Adaptive training solutions require pedagogically sound instructional management that efficiently moderates a learner's experience through content selection, guidance, and feedback. To efficiently moderate learning experiences in a self-regulated training environment a developer must account for multiple facets of the learning process that ultimately impact how people build knowledge and develop skill. In this paper we present dimensions of instructional management that influence dedicated research efforts in support of the Army Learning Model vision to increase the use of adaptive training solutions. We begin by presenting driving requirements associated with this research, followed by a background on the Generalized Intelligent Framework for Tutoring (GIFT) being developed to support this vision. We conclude with four instructional management end-state themes that motivate current and future research efforts, including: (1) guidance and scaffolding; (2) social dynamics and virtual humans; (3) metacognition and self-regulated learning; and (4) personalization and non-cognitive factors.

Keywords: instructional management, adaptive training, intelligent tutoring systems, pedagogy

1. INTRODUCTION

The instructional or pedagogical model in an Intelligent Tutoring System (ITS) is responsible for directing adaptive strategy implementations by acting on learner relevant data and linking strategy calls with context relevant tactics associated with the domain, and supported by the training environment. This involves a tutor agent interacting with the learner (e.g., feedback, questions, hints, pumps, and prompts), as well as the training environment (e.g., scenario adaptations and problem selection), through methods grounded in learning theory. To optimize pedagogical models in adaptive training environments, techniques must be established that define strategy types based on a learner's prior experience and their associated traits and states that affect how individuals create knowledge and develop skill. Techniques are based on prior research in the field and organized around empirical evaluations informing their application and effectiveness (Wang-Costello, Goldberg, Tarr, Cintron, and Jiang 2013, Goldberg, Brawner, Sottilare, Tarr, Billings, and Malone 2012, Person and Graesser 2003).

A barrier to the success of this research is scope. Instructional management as a whole is a large research space with a number of dimensions guiding its implementation. To manage this appropriately, it is important to organize overarching requirements to guide developmental efforts. This strategy lends itself to defining desired end-states that informs design and dictates model representations. In the sections to follow, we first review recognized Army requirements that are motivating this line of research and development; then we present current progress on an ARL program dedicated to the advancement of adaptive training in the military called the Generalized Intelligent Framework for Tutoring (GIFT). This is followed by a review of instructional management research dimensions that cover the breadth of capabilities an ideal system possesses to optimize learning experiences in a distributed environment in the absence of live instruction.

2. DRIVING ARMY REQUIREMENTS

The Army' Training and Doctrine Command (TRADOC) defines Warfighter Outcomes (WFOs) on a regular basis for the purpose of directing and influencing science and technology research within the department of defense. WFOs are used to articulate warfigther capability needs, with advancements in training practices being listed as a critical requirement. For the purposes of our research, four specific WFOs are influencing directed end-states. These include: adaptive training and education systems; big data; training at the point-of-need; and artificial intelligence. In the following sub-sections we give a brief overview of the WFOs of interest and how instructional management research will be applied to address recognized gaps.

2.1. Adaptive Training and Education Systems

This gap is based on the recognition that there is a lack of adaptive solutions to support individual and collective training across the Department of the Army.

What is needed is a capability to assist trainees in the absence of live instruction that adapts to their Knowledge, Skills, and Abilities (KSAs) for efficient knowledge and skill acquisition that transfers to the operational environment.

An effective adaptive training capability is dependent on sound instructional management practices. Instructional management practices are composed of techniques, strategies, and tactics applied to a domain of instruction so as to optimize performance outcomes (Sottilare, Graesser, Hu, and Goldberg 2014). With respect to GIFT, this vector of research is concerned with identifying instructional best practices that associate with all facets of learning, as well as establishing authoring workflows that instantiate those practices across multiple environments of instruction. The goal is to provide adaptive training solutions that are sufficiently adaptive for each individual Soldier and for teams of Soldiers.

2.2. Big Data

The Army recognizes the need for a capability to handle and process an abundance of data associated with training practices to better design and optimize programs of instruction. From a training effectiveness perspective, data is available to evaluate training techniques and strategies applied to observe their effect on training outcomes that associate with skill acquisition and the progression from novice to expert. With adaptive training solutions supporting distributed and collective events, tools and methods can be created to automate data analysis for the purpose of assessing all components of a training event and how their implementation characteristics influenced performance measures.

A goal of instructional management in GIFT is to optimize performance and competency outcomes through personalized training experiences that adapt to an individual's KSAs. A connection between Big Data and instructional management is applying large data sets from prior course interactions to update and improve technique and strategy implementations across all available courses. A challenge with defining instructional management logic in a domain-independent context is that it requires generalizability across applications. An issue with instructional strategy based research is that an approach taken in one domain is hard to translate to a different without performing extensive research to validate its application. In addition, it is difficult define definitive instructional management logic based on these uncertainties. As such, big data can be used to account for this uncertainty by applying machine learning and data mining techniques to assess specific causal relationships between instructional practices and outcomes on performance, retention, and transfer. This application of big data is used to reinforce instructional management models by optimizing itself over time as more and more data is made available.

2.3. Point of Need Training

This driving requirement is based on a recognition that the Army lacks cost-effective and easily accessible learning materials that support a model of training at convenience. To facilitate this perspective, advancements in distributed training practices must be researched to support web-based, cloud-driven delivery methods that allow a trainee to access materials from anywhere with an appropriate network connection.

A goal of instructional management in GIFT is to support a model of training by convenience and to have mechanisms to support this form of education in the absence of live instruction. Effective training applications administered in a point of need capacity requires four primary components to deliver sound instruction: (1) the ability to monitor trainee interaction and behavior to accurately assess performance against a granular concept by concept model, (2) the ability to communicate guidance and feedback messages that correspond with individual performance, (3) the ability to adapt scenario/problem elements to maintain appropriate challenge levels for promoting flow, and (4) the ability to manage an automated After-Action Review (AAR) to review scenario performance and promote reflection on the linkage between outcomes and overall learning objectives. Each of these components are dependent on each other for the purpose of delivering personalized training experiences through an easily distributed, web-based open-enterprise architecture.

In addition, an optimal adaptive training capability will leverage existing course materials to better serve the development of a competency through point of need functions. An example is providing a remedial training activity on an indentified weakness in-between training events to better prepare that individual for the next period of instruction (e.g., recognizing trigger squeeze problems in the EST and providing a remedial multimedia training event prior to the next round of marksmanship instruction on the live range).

2.4. Artificial Intelligence (AI) Capabilities

This driving requirement is based on a need for an automated capability to replicate interactions, complexities, and uncertainties associated with executing mission oriented tasks in an operational environment. AI in education and training associates with the adaptiveness of virtual humans embedded in a training experience, how an ITS manages pedagogical decisions, and how scenarios can adapt and respond to trainee inputs.

A goal of instructional management in GIFT is to facilitate robust AI capabilities that enhance the realism and playability of simulation-based training exercises; specifically those that utilize virtual humans and semi-automated forces. These elements must be embedded with AI capabilities that provide an automated reactive capacity to trainee inputs and actions that adhere to the complexity and uncertainty of an operational environment. In terms of Virtual Humans, these entities must have logic that supports realistic movements and communication exchanges that reflect back to a culture or operational environment. This requires AI embedded within Virtual Humans that accounts for cultural norms and customs, along with the ability for the entity to adapt its behavior based on cues and actions perceived from the trainee (e.g., rolling of the eyes, change in vocal intonation, failing to account for appropriate cultural greeting, etc.).

AI also needs to be embedded in Virtual Humans that enables their use as virtual teammates in a collaborative training scenario. This will allow for effective training of team-oriented missions without the requirement of utilizing an all human team. In terms of semi-automated forces, which are commonly used in tactical training events within environments such as VBS3, AI techniques must be established that allow a group of forces to adapt their movements overtime as it can autonomously learn from actions and tactics executed by a trainee or team of trainees. This will allow a set of enemy forces to better adapt itself, much like in the real world, for the purpose of creating richer training experiences that increase complexity. In addition, AI techniques must be investigated to ease the development of training scenarios to avoid issues of replay-ability. A system such as VBS3 would benefit from technologies that enable the generation of multiple scenarios for training purposes based solely around a defined set of tasks, conditions and standards. This promotes better training because a trainee needs to adapt their application of knowledge and skills to an unknown event, rather than gaming a scenario by learning the various cues and scripts executed by an enemy entity (i.e., knowing an insurgent is hiding behind a specific door in a specific hallway).

3. INSTRUCTIONAL MANAGEMENT FUNCTIONS CURRENTLY IN GIFT

Before we examine specific goals and research interests associated with instructional management in GIFT, it is important to review some high level components of the architecture. This involves an understanding of how information and data is represented, and how these representations ultimately inform the Adaptive Tutoring Learning Effect Chain (ATLEC; Sottilare, Ragusa, Hoffman, & Goldberg, 2013; see Figure 1). The important takeaway of the ATLEC is the flow of data with respect to the selection of an instructional practice. The effect chain is influenced by both historical data (e.g., prior experience, prior knowledge, learner traits, etc.) maintained over time and real-time data captured during a specific interaction. This data is used to adapt instruction on two facets: (1) an inner-loop capacity using data to influence interaction within a single problem or scenario by providing guidance or adjusting difficulty levels similarly to Vygotsky's (1987) Zone of Proximal Development; and (2) an outer-loop capacity that configures the next event experienced by a learner based on assessments from a prior event or through predictions based on historical representations and learner traits (VanLehn, 2006). This might involve selecting a new problem/scenario, managing a remediation event, moving on to a new section of the course, administering an AAR, or ending the course.

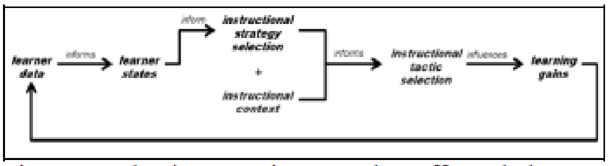

Figure 1: Adaptive Tutoring Learning Effect Chain

In terms of the inner-loop adaptive function, the ATLEC primarily interacts on learner assessments occurring in real-time for both performance and affective related states. Ultimately, raw interaction data is used to infer a learner state from. This involves robust assessment techniques that can accurately gauge an individual learner's performance for a given task, the affective responses they are having within that task, and their estimated competency for the domain that task is designed to train. This inferred learner state is used to inform the selection of an instructional strategy to mediate the learning experience. In the current baseline of GIFT (e.g., release GIFT2015-1 on https://www.gifttutoring.org), the instructional strategies supported for the inner-loop consists of "provide guidance", "adapt scenario", "administer assessment" and "do nothing". These strategies are represented as high-level domain independent descriptors of an action the system can take within a given learner event. These high level actions must then be translated into a specific tactic of execution (see Sottilare, Graesser, Hu & Goldberg, 2014 for a comprehensive breakdown of strategies vs. tactics).

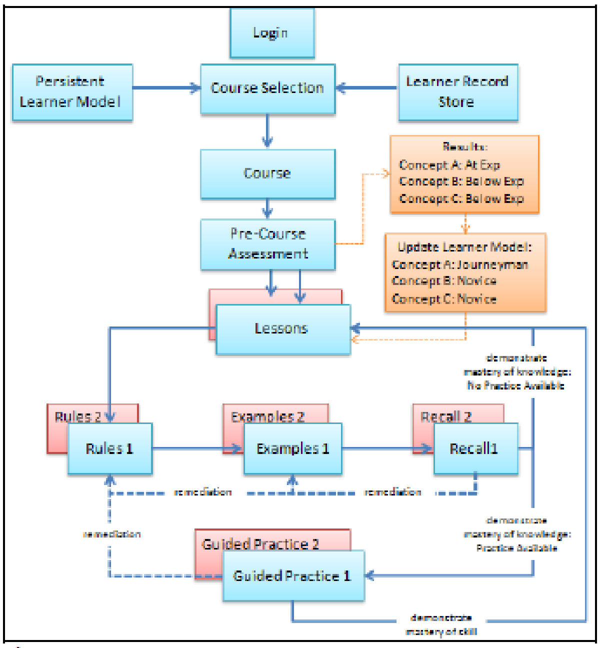

Figure 2: GIFT's EMAP

For outer-loop adaptive functions, components of the ATLEC are administered upfront to configure a lesson's sequence of interaction. Learner data informs strategy selections that associate with David Merrill's (1994) Component Display Theory (CDT). This interaction is currently encapsulated in a tool used by GIFT called the Engine for Management of Adaptive Pedagogy (EMAP; see Figure 2). In the latest GIFT baseline, the EMAP is used to guide a learner through a set of interactions that focus on: (1) the presentation of Rules for a domain or task, (2) the presentation of Examples where those rules are being applied, (3) the administering of a knowledge assessment that gauges a learner's ability to Recall facts, and (4) the administering of a Practice assessment that gauges a learner's skill for performing tasks associated with the domain of instruction (Goldberg & Hoffman, 2015). With a framework in place to support adaptive pedagogical modeling practices, work is required to identify a set of best practices for configuring the inputs and outputs of these models to optimize learning outcomes. To guide this research, requirements are defined that layout overarching instructional principles to inform pedagogical application and reasoning.

4. INSTRUCTIONAL MANAGEMENT END-STATE THEMES DRIVING RESEARCH

In the following section, we review the specific overarching themes associated with instructional management research in GIFT. Each theme is represented as a dimension of research that serves different components of the learning process. While reading through these research thrusts, it is important to conceptualize its application across various training environments and use cases. While these dimensions can be somewhat confined in terms of instructional management intent, how they can be applied across all types of training environments is vast. This includes considering individualized vs. team-based training events, as well as considering the technologies being applied to facilitate the training itself. With these guidelines, four themes will be presented. These include: (1) guidance and scaffolding practices, (2) social dynamics and virtual humans, (3) metacognition and self-regulated learning, and (4) personalization techniques based on cognitive and non-cognitive factors.

4.1. Guidance and Scaffolding

Scaffolding is a term used to describe the application of instructional supports to assist a learner in developing knowledge and skills that the learner would not achieve when left to their own devices. Holden and Sinatra (2014) define scaffolds as a temporary application of strategy that is gradually removed ('faded') once a learner demonstrates an increase in proficiency or skill. The word 'strategy' is used loosely here, as it can be a number of interventions that range from guidance, feedback, scenario/problem manipulation, and remediation. Prior to the advent of computer-based training environments and ITSs, an expert adult or peer (e.g., parent, teacher, classmate, teammate, etc.) provided scaffolding practices. This individual acted as an expert, a facilitator of KSAs required for learning, a motivator, a model, and a means for the learner to reflect (Puntambekar & Hubsher, 2005). As such, much of the applied guidance and scaffolding practices in adaptive training environments are based on what effective instructors and tutors do in real life. In examining models of expert human tutors, several themes have been identified for effective interaction:

- Demonstrate credible knowledge of the domain under training (e.g., tactical combat casualty care);
- Read cues from the learner and adapt instruction in real time to meet their changing needs;
- Encourage question asking;
- Provide indirect feedback;
- Assess learning often

When designing scaffolds and the logic associated with their execution, three dimensions require consideration. These are: What to scaffold, when to scaffold, and how to scaffold (Azevedo & Jacobson, 2008). With respect to GIFT, each of these dimensions must be conceptualized in a domain-agnostic fashion. The first consideration that will dictate how to proceed is based on available tools and methods for scaffolding. In this vein, the mode of interaction and the specific training application itself will determine what approaches can be implemented. For instance, interacting in VBS3 affords different scaffolding strategies when compared to interacting with a negotiation trainer on a tablet. The type of state (e.g., performance, affective, etc.) information being monitored in the learner model, the type of communication interfaces available for presenting information (e.g., GIFT's Tutor User Interface, Smartphone, Smart Glasses, haptic device, etc.), and the type of adaptations supported by the training application (e.g., changing the weather in VBS3 to increase the complexity of scenario) all impact the types of scaffolds that can be built to support a specific course or lesson.

Once you recognize the available tools to trigger and support scaffolding practices, determining what to scaffold must be addressed next. What to scaffold can be represented in a generalized fashion and is based on defined learning objectives and barriers to a learner performing successfully. This could include scaffolding specifically on the cognitive level that accounts for the domain or the task procedures themselves. Or scaffolds can account for different constructs associated with the learning process, such as metacognition (i.e., to regulate goal planning, performance monitoring, help seeking, etc.) and affect (i.e., to regulate motivation, boredom, frustration, confusion etc.; van de Pol et al., 2010). Recognizing what you want to scaffold along with what tools and methods you have to support those types of interventions will lend itself into building the specific scaffolds for implementation.

With scaffolds conceptually established, the next step is building logic for determining when to apply a scaffold and how to appropriately fade/adapt its use to promote efficient transfer of execution. A common perspective to account for this challenge is based on Vygotsky's (1978) ZPD. ZPD is an optimal and efficient zone of learning that elevates the student from his/her current and actual developmental level to one of more potential through balancing challenge with ability and through formative guidance to enhance skill. In its simplest form, the ZPD creates a formalized state space representation that enables a system to contextualize what a learner is experiencing for a given training domain. For example, if a training system launches a scenario with a preconfigured difficulty setting of expert and a trainee's skill state is defined as journeyman, the system may trigger specific scaffolds that are intended to support the maturation of skill levels to meet the challenge level of a selected scenario. In this instance, if performance assessments associate execution with increased skill levels, then the system must be able to recognize this shift and fade scaffolds. From the opposite end, if a learner demonstrates skills that fall below their predicted ability levels, the system must be able to appropriately trigger scaffolds to compensate for that inaccurate upfront classification. This must be possible for both dynamic scenario-driven tasks as well as for training applications that use discrete problem sets that allow adaptation between each problem.

4.2. Social Dynamics and Virtual Humans

In this research sub-vector we review end-state goals associated with the role of social dynamics and virtual humans in managing instruction within adaptive training environments. This line of research associates with tenets of Social Cognitive Theory in that learning is theorized to be an inherently social process (Bandura, 1986; Vygotsky, 1987). As such, techniques should be applied to account for high valued social elements that can potentially improve a piece of educational technology. In addition, Army task domains can involve highly socialized interactions. To support these task characteristics, adaptive training systems should account for the types of interactions a Soldier might face (e.g., negotiating with a village elder) and the variables that may influence their course of action (e.g., cultural norms for greetings and negotiations). From an adaptive training perspective, social dynamics and virtual human research is focused on:

- Using technology and AI to replicate interactive discourse common in educational and operational settings;
- Using technology to embed social elements in the environment, such as Virtual Humans, to create a social grounding function for delivering information/guidance;
- Using technology and AI to create realistic and reactive Virtual Humans as training elements in a simulation or scenario (e.g., role player, teammate, etc.);
- Using technology to create a social forum for the purpose of supporting peer-to-peer and collaborative learning, both from a real-time perspective as well as from a time-agnostic approach allowing interaction at convenience.

Each referenced focus area is based on a specific social element of interest to the GIFT community. Of importance is the application of these elements within the standardized architecture inherent to GIFT. Specifically, how can the tools and methods built to afford these capabilities be translated to support ease of application within any type of training event and within any type of training environment? Each identified element associates distinctly different research questions and associates distinctly different scientific disciplines. It is a very broad sub-vector of instructional management with many dependencies to other elements of the GIFT research program.

In the case of using ITS technologies to replicate interactive discourse, an end-state goal is to establish state of the art natural language processes to create a robust tool capable of dynamic Q&A exchanges. In this instance, we want a training environment to be able to push a question to a learner and we want a trainee to be able to ask questions of the ITS, ideally through natural language and open response input methods. As highlighted above, a characteristic of an effective tutor is one who encourages a learner to ask questions. This process in itself promotes learning through abstraction and reflection. As such, we need a discourse capability that can accurately interpret user responses, and intent, as it relates to the semantic space of instruction and we want this capability to associate with pre-existing training applications (i.e., use natural discourse Q&A in parallel with executing a VBS3 scenario). This capability can be applied in multiple training instances and under many conditions. This includes (1) discourse to support reflective Q&A sessions to promote higher order cognitive thinking, (2) discourse to support training events that involve social exchanges to meet certain negotiation objectives, and (3) discourse to support realistic communication with virtual entities in an environment that associate with both friendly and opposing forces. Much like scaffolding capabilities, the application of natural language discourse in an adaptive training event associates many dependencies across the various research vectors. Specifically, domain modeling, authoring processes and architecture requirements are the greatest considerations when it comes to implementing this approach to instructional management.

Next, virtual humans are identified as key technology pieces in extending adaptive training experiences to account for varying roles in the learning process. From an ITS support perspective, Virtual Human research is focused on the application of technology to provide an interactive communication layer that grounds all system generated prompts with a social element. An overarching intent is to facilitate interaction and communication with a computer in a way that is natural and realistic. The goal is to support highly engaging and interactive experiences through socialized sequencing of interaction and enhancing system communication by interfacing with a learner through comfortable modalities. Much of the prior research in this area focuses on the trust and perception of technology in facilitating a role traditionally managed by a person and the impact on motivation and effort (Kim & Baylor, 2006; Holden & Goldberg, 2011; Veletsianos, 2010; Veletsianos, Miller & Doering, 2009).

Virtual Humans can also facilitate critical role players in training events. In these instances AI methods allow virtual entities to realistically react to environmental stimuli and user inputs in a non scripted fashion, making the experience more natural and engaging.

Lastly, social media technologies are believed to offer innovative tools for instructional management practices that have yet to be fully taken advantage of. As a result, research is required to better understand how best those tools and methods can be applied.

4.3. Metacognition and Self-Regulated Learning

Self-Regulated Learning (SRL) theory describes the process of taking control of and evaluating one's own learning and behavior (Butler, Cartier, Schnellert, Gagnon & Giammarino, 2011). As a higher-order cognitive function, SRL is guided by metacognitive processes (i.e., the knowledge and regulation of one's own cognition), strategic actions and behaviors (i.e., planning, monitoring, and assessing one's own performance), and motivational components (i.e., goal setting and self-efficacy) (Flavell, Miller & Miller, 1985; Schraw, Crippen & Hartley, 2006). These functions allow self-regulated learners to set goals, monitor their progress toward defined goals, and adapt and regulate their cognition, motivation, and behavior in order to reach the specified goals (Anderman & Corno, 2013; Bransford, Brown & Cocking, 2000). These characteristics also associate with desired competencies within the Army Learning Model that adaptive training solutions are intended to instill. As such, research in the instructional management vector is focused on the application of models and strategies for enhancing metacognitive awareness and regulation.

This approach to instructional management varies from traditional guidance and scaffolding techniques as it focuses on behavior and application of strategy, rather than on task dependent performance. One such question is based around GIFT supporting SRL, and the efficacy of defining persistent metacognitive strategies that can be applied across domain applications. Currently, GIFT pedagogy is heavily focused on error-sensitive feedback. It works with system authors by translating instructional strategy recommendations communicated by GIFT's pedagogical module into tactics as they relate to the specific training context. These tactics are used during ITS runtime and are selected based on a learner's individual differences. At the current moment, feedback in GIFT is domain dependent and requires explicit content linked to each concept modeled. When it comes to metacognitive feedback, what are the implications to a domain-independent approach? First, modeling techniques need to be developed to monitor an individual's practice of metacognitive strategies that can be expressed in a generalized format. An example would be incorporating a combined modeling approach, as described in Biswas, Segedy, and Kinnebrew's (2014), or by adapting a help-seeking model, as highlighted in Koedinger, Aleven, Roll, and Baker (2009).

One such approach is researching and establishing models based around commonly available GIFT interactions (e.g., request hint button). How can we use these available data inputs to build a representation of how effective students use the interface to solve problems and troubleshoot errors? This approach can aid in detecting learners not practicing good metacognitive behaviors through machine learning and data mining practices and can be used to trigger feedback interventions to improve their understanding of available strategies. With modeling techniques in place, generic strategies and tactics can be identified that are based around effective metacognitive behavior. In this instance, the generic strategy of 'provide guidance' can be linked with a generic tactic of 'you are ignoring available resources', thus preventing any explicit authoring from a system developer. While tactics can be represented in a domain-independent format, their effect is relatively unknown.

4.4. Personalization (Occupational and Non-Cognitive Factors)

Current ITS systems, such as GIFT, offer more flexibility and features than systems and computer programs that were developed in the original context personalization research conducted in the 1980's and 1990's. Additionally, as a domain-independent framework, GIFT can be used to examine the impact of context personalization in a variety of other domains, whereas in the past the research has primarily focused on math instruction. One approach to context personalization research that can be taken with GIFT is to do work similar to Ross (1983), in which the context of the problems and materials are specifically matched or mismatched with the individual learner's specialty area. In the context of military training, a Soldier's Mission Occupational Specialty and near-term assignments can be used to personalize a training experience to better prepare that individual for the environment they will be operating within.

Rather than using mathematics as the domain of interest, a military relevant domain can be chosen. Providing materials that are matched to the individual learner's specialty area is expected to have a positive impact on learning and attitudes toward the experience. Learning outcomes are expected to be improved as the individual will not already have an understanding of the context of the provided examples, but also will be able to easily see why it is relevant to their own job.

In order to support personalization additional studies could examine the impact of allowing learners to select the context of the questions they will receive based on their own preferences or the task that they will be engaging in. In many military-related tasks there are subtle differences in the task that will be performed based on the geographic location of their assignment. For instance, if an individual is tasked with interacting and negotiating with individuals from a culture other than their own they may engage with a negotiation tutor. However, depending on the culture that they are to engage with there may be different phrases or customs that should or should not be used. The basic elements of negotiation will be similar, but the questions and materials can be edited to have geographic and culturally specific examples that will be more consistent with the actual experience the individual will have. Research can be conducted on the level and types of material and assessment personalization that results in positive outcomes and performance.

5. GIFT DEPEDENCIES IN SUPPORT OF INSTRUCTIONAL MANAGEMENT RESEARCH

Managing instructional strategy selection and tactic delivery is dependent upon multiple components of GIFT. This associates domain modeling to apply context to a pedagogical decision, learner modeling to provide trainee relevant information that triggers a pedagogical intervention, authoring to provide a means for building these linkages and representations, and training effectiveness to determine if a strategy or set of strategies had an effect on performance related outcomes. This highlights an important point; while each of the aforementioned components of instructional management has separate processes, the architecture is the component that dictates implementation design and development.

In GIFT, instructional management takes place in two modules/processes within the learning effect model. One process is instructional strategy selection within the pedagogical module. The second is within the domain module where specific tactics or actions are selected based on the strategy selection and instructional context. An important component of instructional management is translating a generalized strategy into a tactic that can be executed within a specific training environment. This requires understanding what knowledge components make up a domain and what tools are available to guide a learner and adapt the training event. In addition, domain modeling plays a critical role in enabling the use of reusable learning objects. When applying instructional management practices in an outer-loop capacity through GIFT's EMAP, a well-designed domain model can be used to identify content that can be presented to a learner along with data that supports its application. This supports ease of authoring as well, as a developer can leverage existing content if their domain model has overlap with existing course representations.

In terms of architecture, end-state goals of GIFT require potential integration with a number of technologies that facilitate varying roles of instructional management practices. These technologies include tools and methods to support content management, natural language processing, text to speech processing, virtual human authoring and configuration, social media framework connections, and training application manipulations (e.g., manipulating the weather in a virtual world). In addition, specific architectural modifications will be required to perform tasks inherent to the current standards of GIFT, including methods to create messaging templates used to auto-populate feedback scripts with context relevant information established in log files, the ability to personalize strategy selections on an outer-loop and inner-loop capacity across learners and teams of learners, and the application of actionable metadata and xAPI statements to appropriately link learner information and prior experience with appropriate training and optimized configurations. In dealing with a domain-agnostic intelligent framework such as GIFT, the use of machine learning and data mining techniques are required to reinforce and optimize pedagogical logic over time.

6. CONCLUSION

The foundational goal of adaptive training research at the ARL is to *model the perception, judgment, and behaviors of expert human tutors* to support practical, effective, and affordable learning experiences guided by computer-based agents. To this end, four primary themes in instructional management research for adaptive training systems were identified and discussed. This line of research is important to advance adaptive training solutions into a new state-of-the-art that optimizes training experiences through customized pedagogical practices.

Following the development of a pedagogical framework that accounts for these four themes of instruction, extensive empirical investigations will be conducted to validate their application across numerous domains of instruction. The results of these experiments will be used to refine pedagogical policies, with a goal of establishing reinforcement learning methods that automate modifications to the instructional strategy selection techniques.

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