Integrating the outer loop: Validated tutors for portable courses and competencies

Elliot Robson[1], Fritz Ray[1], Anne M. Sinatra[2]
Eduworks Corporation[1], U.S. Army Research Laboratory[2]

INTRODUCTION

The Generalized Intelligent Framework for Tutoring (GIFT) is a broad and flexible framework for developing and delivering training. GIFT currently provides support for best practices and most effective pedagogy in the tutoring context, however, it is limited in providing support in the course development process. In this paper, we present the GIFT Structural Equation Modeling (GIFT-SEM) module for doing rapid analysis and validation of the concepts and concept models used to guide training development. We believe this is one piece of a suite of validation tools that will be used to allow GIFT authors to identify and share effective pedagogy, concept models, sequencing, and learning resources. This validation suite will provide the evaluation necessary to integrate GIFT tutors into synthetic training environments (Dumanoir, 2015) and larger service oriented architecture (SOA) ecosystems. Additionally, validated tutors and pedagogy allow authors to learn from each other's work, share validated training throughout the GIFT ecosystem, leverage near and far transfer of learning, and validate external resources within their domain.

Validation is not only central to a vision of GIFT performing a complete iterative instructional design loop from conceptualization to evaluation, but it supports periodic refinement of instructional materials, which is important for extending the lifespan and reuse of training. Most successful long-term training development and creation strategies include validation and iterative improvement. For this discussion, we chose to use the ADDIE process because it is a general process used by many instructional designers (Molenda, 2003). ADDIE: analyze, design, develop, implement, and evaluate, is an iterative process that constructs and refines instructional material.

In GIFT, the ADDIE process has been supported through the use of tools to assist in each stage of the process. Analysis of the subject domain can be done by subject matter experts, or through tools such as TRADEM (Ray, 2014). Design, Development, and Implementation of the tutor are accomplished through GIFT Authoring Tools, Content Authoring, GIFT Cloud, and more. With the integration of the SEM component, GIFT has the first piece of the evaluation module necessary to complete the ADDIE process (Branch, 2009).

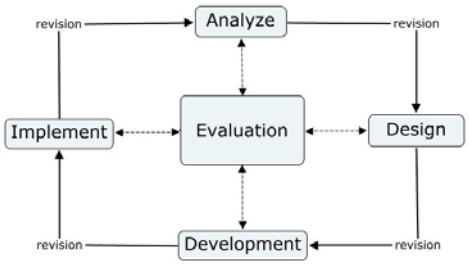

Figure 1: ADDIE Process

In this paper we will discuss authoring in GIFT and how GIFT-SEM provides a roadmap for integrating evaluation into the GIFT Cloud workflow. In addition, we will outline a broader GIFT evaluation module along with a description of how integrating GIFT into a SOA can extend the ADDIE process and enhance the capabilities of GIFT. Finally, we will discuss the long-term advantages of a full instructional design loop in GIFT and how GIFT can inform a larger SOA.

BACKGROUND

Course Authoring In Gift

GIFT is a domain-independent framework for creating intelligent tutoring systems (ITSs). GIFT has been designed to promote reusability of materials, reduce the time that it takes to author an ITS, and lower the skill level needed to author an ITS (Sottilare, Brawner, Goldberg, & Holden, 2012). Due to the generalized nature of GIFT, there is a great deal of flexibility available in regard to how to author a course. Based on the subject matter, the student level, and even the preference of the course designer there may be different functionality that is utilized on a course-to-course basis.

The GIFT Authoring Tool has been updated and refined over time, and allows the individual who is creating the course to select and organize the course elements that they will need, the ability to create surveys/question banks, and the ability to set up an adaptive courseflow. Before beginning the authoring process, the concepts that are associated with the course should be determined and established by the author based on their own instructional design and domain knowledge. These concepts are then used as tags throughout the course authoring process. The GIFT course authoring process supports most common forms of content, including: word, pdf, ppt, HTML, slideshows, and more. A screenshot of the GIFT Cloud Authoring Tool interface as of GIFT 2017-1 is in Figure 2.

In the ideal GIFT authoring process, the individual who was authoring the course would bring all of their course materials, survey questions, and desired adaptations and work with the system to create their adaptive course. The design and ordering of the material that they use would be up to them, but may be informed by best practices, external concept models or the user's knowledge/beliefs about the content. In addition, the GIFT-SEM module allows users to validate these beliefs about course sequencing. When implemented, knowledge extracted from courses using the GIFT-SEM evaluation module can also be used as a basis for the selection of course order. The ability to use GIFT evaluation modules to assess the current state of a course based on learning outcomes allows GIFT to provide a clear path to iterative refinement of the tutor, eventually resulting in a proven and validated tutor.

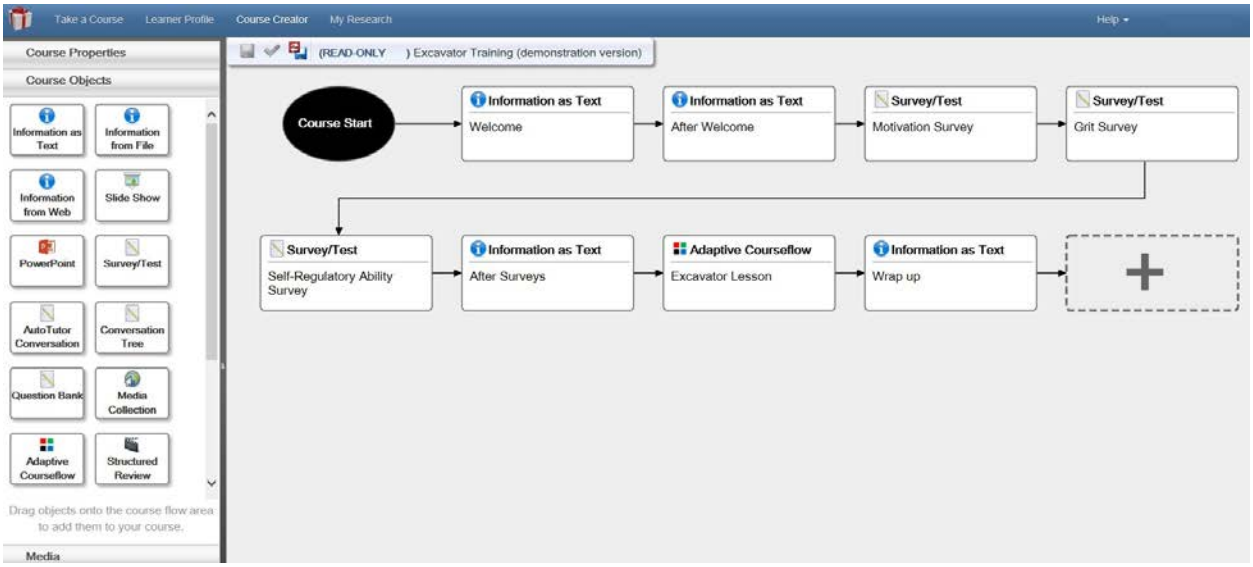

Figure 2: GIFT Authoring Tool Interface. The Course objects are on the left. The course flow is on the right.

GIFT-SEM in GIFT

GIFT-SEM is a tool that performs analysis and evaluation of a tutor, and provides a report describing the general 'fit' of learner data with the course sequence and concepts. To use GIFT-SEM, an author creates a course, utilizing concepts, surveys and question banks, optionally skipping content. During the course creation process, the user translates their beliefs about the ordering of underlaying concepts into pedagogy through the sequencing of elements and the concepts that elements are tagged with. This concept map, as represented by the concepts selected during course creation, is the main target of analysis for GIFT-SEM.

After the course has run, the author uses GIFT-SEM to analyze the course based on the performance of students during the course. Finally, the author then publishes and collects results in an experiment and uses the GIFT-SEM tool to perform analysis. This analysis produces a report (Figure 3) that provides a high-level summary of how well the author's concept model is supported by the student results. In addition, the final output details the statistical checks used to reach this conclusion. This allows users with multiple levels of statistical sophistication to use GIFT-SEM effectively. These reports allow all users to identify cases where their beliefs about the concepts and concept ordering of a course is not supported by actual student results. In cases where the results are poorly supported, it is possible to use GIFT-SEM to explore other hypothetical concept mappings. This "what if" exploration allows users to discover more effective pedagogic sequencing and identify their own misconceptions about the concepts that underlay content.

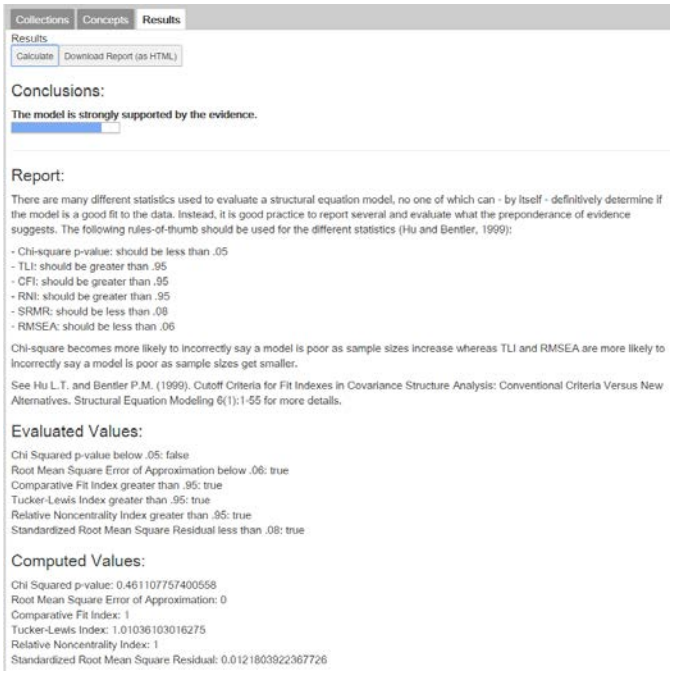

Figure 3: GIFT-SEM Detailed Report

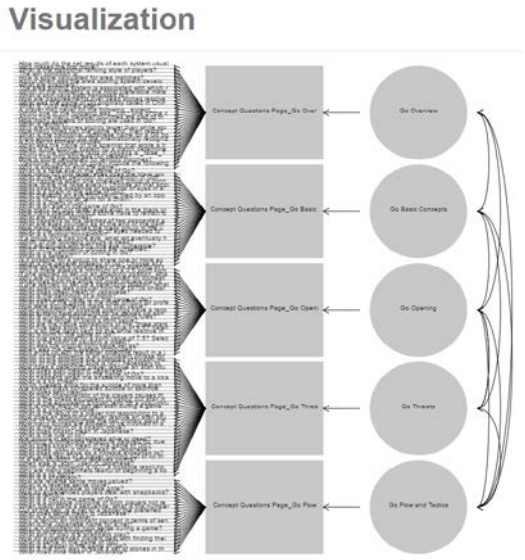

Figure 4: GIFT-SEM Concept Map Visualization

GIFT-SEM is the first internal evaluation tool for GIFT. It allows experts and authors to evaluate and validate concept models used to design and develop training using SEM. Using actual student results, GIFT-SEM analyzes how well the learning outcomes support the concept model and suggests easily understood next steps to the user. GIFT-SEM supports two primary types of investigation: confirmatory analysis where an expert uses SEM results to confirm or reject the concept model; exploratory analysis where an expert tests different concept models against student outcomes to see how well a candidate model is supported by the evidence.

In order to successfully apply causal modeling (SEM), it is necessary to identify the concept model being used by a piece of training or content. Currently, GIFT-SEM extracts the concept model by tracing the learning path using the concepts mapped in GIFT to assessments and other

content. GIFT Cloud provides data through xAPI and GIFT's internal logging format and tools. However, extracting the information necessary to identify the learner's path and support causal analysis requires an additional interpretation layer to be applied to GIFT logs. The current interpretation layer built for GIFT-SEM is designed with a larger GIFT evaluation module in mind: it extends the existing GIFT data model and provides support for the evaluation of pedagogic approaches, training outcomes, and content ordering. In GIFT-SEM, we visualize the concept map portion of the interpretation layer's analysis of the GIFT logs (Figure 4). The GIFT-SEM visualization gives a high-level view of the gift course from a concept map perspective. In figure 4, the left side shows every question contained in the course, with the surveys in the middle and finally the concepts on the right. Links between concepts are inferred from the logs based on author tagging in the GIFT authoring tool. We believe that the interpretation layer used in GIFT-SEM to analyze and visualize GIFT log data could be reused and expanded in other analysis applications and support non-xAPI data sharing between GIFT and other software.

SOAs In Education

Validation of tutors is important to GIFT as a method of improving pedagogy, but it is also a core function needed to cement GIFT as the central authority within larger systems that make use of multiple pieces of software. Specifically, SOAs are large, distributed collections of software components that fulfill the individual roles necessary to deliver a complete user experience (Papazoglou, 2003). In a SOA, some parts of the architecture are shared by all the components; for example, user management and student learning plans. By separating the role of each component, and defining clear protocols and boundaries, specific components can be reused across user experiences. This creates an ecosystem where there are many common components that provide large amounts of functionality, allowing features such as single-sign-on, shared learner profiles, shared concept models, common resource stores, and more.

SOAs, however, are relatively new to the domain of education (Lavendelis, 2012). While an educational SOA can utilize several common components, such as user management, content repositories, and more, there is less consensus among educational protocols for representations of learner knowledge, affective state, pedagogical practice, and other topics specific to education. Additionally, existing non-SOA Learning Management Systems (LMSes) provide a comprehensive, if monolithic, solution and remain difficult to displace.

Globally, SOAs are increasingly common and provide options for public and shared components common to the entire world (Bauer, 2013). In education, this opens up the potential to implement shared components from a broad number of sources, and focus development on specific educational problems and goals. In GIFT, integration into SOAs is an opportunity to integrate with other components that provide services beyond the GIFT framework. Evaluation modules in GIFT are a cornerstone of this effort because they change GIFT from an authoring tool within the SOA ecosystem into a provider of validated tutors that provide gold-standard information for other components.

GIFT IN AN SOA

GIFT Cloud, when embedded in one or more SOAs as shown in Figure 5, would enable use of the full ADDIE process to produce effective and evaluated tutors that interoperate with other components in the respective SOA to contribute to a persistent learner profile that syncs with the GIFT outer loop. This alignment between the GIFT learner data and the learner profile maintained by the SOA supports heavy customization of content both through adaptive course flows within GIFT and adaptive content from external components. With GIFT-SEM and other evaluation modules,

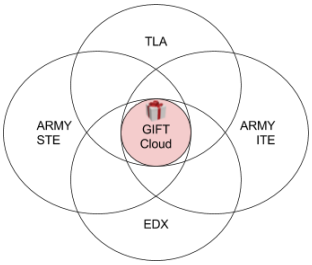

Figure 5: GIFT in SOAs

validated GIFT tutors will be able to interoperate among a network of validated learning activities, including smart content, ITSs, and simulations, providing a comprehensive, connected learning experience. This outcome is essential to systems such as the Army Integrated Training Environment (ITE) and future Synthetic Training Environments (USAAC, 2017). To support these use cases, we demonstrate the current GIFT Cloud workflow enhanced with new ADDIE-aligned processes that support shared competencies, metadata and other forms of interoperability.

Enhancing ADDIE for use in an SOA

GIFT is in the process of being integrated into a number of SOAs ranging from a SOA with persistent learner profiles, competency tracking, and content repository, the Total Learning Architecture (ADL, 2017), to coarse grained SOAs such as edX. To support an instructional design process that fits into a service oriented architecture that has components beyond GIFT, it is necessary to add new information at each step of the ADDIE process. The additional information needed to integrate ADDIE, as implemented in GIFT, into an SOA is outlined here:

Analyze: In the first step of the ADDIE process, a designer analyzes the domain of instruction with the assistance of a subject matter expert (SME). To maximize interoperability and compatibility, a list of concepts is constructed from existing knowledge of the domain. In well articulated domains, such as mathematics or history, this is simple. In the absence of existing taxonomies, steps should be taken to use standard and reusable vocabulary in naming concepts, and the resultant list of concepts should be published and made ready for reuse. For example, in edX, an SOA, there are no authoritative concept lists, so authors must identify GIFT concepts for their course, and align them with other course learning objectives.

Design: The designer identifies, acquires, and conceives new content. This content is selected from other portions of the SOA that are focused on content creation, curation, storage, and alignment. In an integrated SOA, the GIFT evaluation/interpretation layer will align with skills, learning outcomes, competencies, and other learning objects used in the SOA. This content should be aligned at the appropriate level of granularity and maintain interoperability with the other SOA components. This is currently done by using standard forms like LRMI alignment syntax (ASSESSES, TEACHES, REQUIRES). One example SOA, the TLA, uses persistent universal resource identifiers (URIs) to maintain alignment between GIFT, content sources, competencies, and learner data.

Develop: The designer imports content and constructs the GIFT tutor, in accordance with the analysis and design. In this step, the designer uses pre-tests, adaptive tutoring elements, and other concept-aligned entries in GIFT, as well as ensuring correct reporting data is available to the GIFT Evaluation/Interpretation layer and other SOA components. The reporting data in the development step is crucial for validating the tutor, the design of the course, resources used in the tutor, and the concept model the tutor is based on. During this development phase, the metadata and information to be gathered from the tutor is selected. This reporting data includes any data the author or GIFT will to collect during the course. Static information and metadata is stored using persistent syntax like the LRMI alignement syntax, and activity data is generated by instrumenting the content with xAPI events. Currently, many SOA elements are designed so that they have a base set of xAPI statements that are always instrumented. For example, quiz questions will always report the answer entered by a student. Cutting edge software also includes ways for instructors to easily instrument additional xAPI events of interest for their course. For example, an instructor might want to know how long a student spent on a question. This reporting is a key feature to enable the course to adapt to the needs of the learner. By reporting data to the SOA, GIFT enables micro and macro adaptivity.

Implement: The designer implements the tutor. Values for concepts used in GIFT may be acquired from local learner data, but may also be loaded from other portions of the SOA. Data and logs of student

actions and results are stored locally while xAPI and other reporting protocols are used to inform other learning systems. For example, in the Army ITE vision, information about student learning and mastery can be passed between GIFT enabled training stations in a training center.

Evaluate: Finally, the designer may evaluate the course. Currently, GIFT-SEM is the only evaluation tool available in GIFT, so the only analysis provided by GIFT to the SOA is validation of the concept model. Validated concept models, and other future validated content, will allow GIFT to quickly repurpose, update, and reuse successful portions of content, as is normally done in ADDIE. It will also allow the evaluator to evaluate data in the context of the entire SOA, informing both the effectiveness of GIFT tutors and the quality of data and resources coming from other parts of the SOA.

EVALUATION

GIFT Evaluation/Interpretation Layer

The GIFT Evaluation/Interpretation Layer is currently built into the GIFT-SEM module to interpret GIFT logs and provide data and visualization of the concept map. However, this module has been designed to manage data extraction, interpretation, and formatting for use in multiple evaluation modules. We believe that this, or another interpretation layer like it, is key for centralizing GIFT as the heart of an SOA. The data may be ingested from two primary sources: GIFT logs and xAPI statements from GIFT or an SOA that GIFT Cloud is embedded in. By providing a central data store and format, the interpretation layer ensures that GIFT evaluation modules will maintain interoperability and the validations they provide can be transported throughout the GIFT and SOA ecosystem.

GIFT Cloud: Log Analysis

As a computerized tutoring system, GIFT produces vast quantities of information during execution that can be difficult to process without specialized tools and skilled personnel versed in analysis techniques. The implementation of GIFT-SEM focuses on providing a holistic analysis of the tutor as well as a guide to interpreting the output of that analysis. To accomplish this, GIFT-SEM parses logfiles generated in GIFT for events pertaining to particular concepts, such as the execution of a survey or question bank, the concept model's internal ordering of concepts, as well as learner, time and state data. Using this data, GIFT-SEM builds an intermediate model based on the concepts in GIFT with pathways informed by learner paths in the system. Data is attached to each question, survey, and concept node, compiled into a SEM model, and calculated. The process allows for modification of the intermediate model before SEM analysis is performed, which enables exploratory, and possibly other, forms of analysis.

SOA Integration

In implementations of SOA, there is an expectation that GIFT and other components shall provide reporting capabilities that affect both the real time operation of the system, and provide long term analysis and evaluation capabilities at a whole-system level. It is conceivable that in order to evaluate a GIFT tutor, one must consider information from other systems, especially if frameworks, models and other learning objects are shared between GIFT and other components. We foresee a bidirectional interaction with reporting technologies such as xAPI as well as common learner models to answer necessary questions of evaluation, to determine the effectiveness of a tutor in influencing future learning activities, and in incorporating information from real world application of skills taught by GIFT.

Validation and Transportability of GIFT Tutors

The above outlines tools needed for iterative refinement of tutors and sharing of validated best practices in GIFT and within an SOA ecosystem. Today, the use of GIFT-SEM allows for the user to explore

multiple sequences and analyze how well different course sequences support the author's underlying concept model for the domain. With the addition of the tools discussed above, it is possible for GIFT users to analyze tutors in multiple ways (sequencing, pedagogy, competence, etc) and make updates to the tutors based on these analysis. The process of results-driven updating not only creates validated tutors that provide more effective pedagogy, but is also a vehicle for higher-level transfer of best practices between authors. Using GIFT-SEM to validate a concept model for a domain has implications for the sequencing of that specific tutor, but also leads to a better understanding for that author of how the domain works. This kind of learning, when curated, is a valuable resource for new and experienced instructional designers. The creation of more evaluation modules adds additional dimensions to GIFT's ability to validate individual courses and identify best practices and pedagogy.

Today, the state-of-the-art in instructional design and content reaches beyond the boundaries of GIFT and into the SOA ecosystem to incorporate conceptual objects that represent and measure course and student data. Increasingly, a student profile that shares measurements of micro-skills, like how a soldier pulls the trigger on a rifle, and underlying macro-abilities, like mathematical intuition, is at the core of SOAs. For example, the competency frameworks used by the TLA allow for results from validated GIFT tutors to be flowed into other portions of the SOA, helping produce adaptive experiences that result in improved learner outcomes. The Army has comprehensive skill frameworks, found in Army Instructional Manuals that can be used to track readiness, adapt content, and select future programs of study. When a tutor is validated, its results are reliable, making them usable by other systems. When a tutor is validated, and GIFT is in an SOA ecosystem, its results are both reliable and portable to the rest of the components of the SOA. This is one way how advanced pedagogy, adaptive content and course-flow, and better student learning can be best supported.

There are three primary types of validation in GIFT that support the ADDIE process: validated concept models, validated pedagogy, and validated resources. Currently, GIFT-SEM allows for concept models to be validated and shared. The addition of more GIFT modules in the evaluation portion of ADDIE will support validation of pedagogy, sequencing, and resources resulting in fully validated GIFT tutors. When integrated into an SOA, this will allow for both transfer of effective best practices across authors and support new authors in developing higher quality tutors.

The validation of GIFT tutors in their respective domains is independently useful, however, alignment of tutors with learner profile data creates the possibility of adaptive content that adapts based on existing information known about the learner rather than a time consuming pre-test. This reduction of overhead provides a force-multiplying effect when combined with validated training systems, as individual lesson plans can be reliably calculated and recalculated in real time, saving time, money, increasing engagement and, presumably, creating better outcomes.

CONCLUSIONS AND RECOMMENDATIONS FOR FUTURE RESEARCH

In this paper we demonstrate the impact of an iterative ADDIE process within GIFT, and furthermore discuss the potential of an expanded ADDIE that allows GIFT to validate pedagogy, tutors, and concept models. Additionally, we explore the role of GIFT as a component in an SOA, and its importance as a source of data for analysis and evaluation. Finally, we make recommendations for potential future development that will improve GIFT's role in an SOA.

GIFT-SEM is the first step to closing the ADDIE loop in GIFT. It provides the ability to evaluate, but is limited in its evaluation to the concept model. In order to fully support the ADDIE process, GIFT needs a more robust set of evaluation modules that are able to evaluate tutor content, pedagogy, and sequencing. To support these modules, we recommend using the GIFT extraction/interpretation layer that has been built as part of GIFT-SEM. This layer currently ingests GIFT logs and extracts data from them in a

machine and algorithm actionable format. In the future, this layer could be expanded to also ingest xAPI or other data coming into GIFT from other components of a SOA.

Building on the foundation of the ADDIE loop in GIFT, we foresee expanding ADDIE to include data interoperability and standards alignment that will allow GIFT to evaluate tutors in the context of other systems based on both GIFT's learner outcome data and learner information gathered from the SOA's ecosystem. Validated tutors, pedagogy, and other elements of GIFT tutors are the cornerstone of GIFT's role in a SOA ecosystem. By providing tutors that have gone through design iterations and have been validated against student outcomes, the GIFT output serves as a reusable repository of best practices and existing tutors for the entire SOA. To seamlessly integrate GIFT into large SOA ecosystems, the many powerful, well researched and validated components must each be accessible by the other parts of the SOA.

Future research will determine how GIFT can best function as the central SOA authority, how access protocols should be technically defined, and how services can be written to provide these capabilities to other systems. Finally, we believe that this future research will uncover new ways that GIFT can utilize and be utilized by components of the SOA to provide better pedagogy that is more relevant to learners and provide the best possible learner outcomes.

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ABOUT THE AUTHORS

Mr. Elliot Robson *is the VP of Research and Operations at Eduworks Corporation and Principal Investigator on GIFT-SEM. He is an expert in data analytics and education with particular expertise in analysis, extracting meaning, and data structures.*

Mr. Ronald "Fritz" Ray *is the Chief Architect at Eduworks Corporation, an expert in GIFT, and designed GIFT-SEM. His interests are in software and data modeling, interoperability, reuse, and security. In his spare time, he replaces specialized hardware devices in his house with Raspberry Pis.*

Dr. Anne M. Sinatra *is an Adaptive Tutoring Scientist and Research Psychologist at U.S. Army Research Laboratory. She is the team modeling vector lead on the GIFT project's Adaptive Training Team. Her background is in human factors psychology, cognitive psychology, and education.*