

# **xAPI in Action: Field Validation of Bridging Interoperability Gaps in Medical Training with Generalized Intelligent Framework for Tutoring (GIFT) and Competency-Based Learning**

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## **ABSTRACT**

Military medical training faces significant interoperability challenges due to disparate and legacy data standards (Pettitt & Nortfleet, 2024), hindering integration of diverse training technologies and limiting effective competency tracking across interdependent environments technologies and limiting effective competency tracking across interdependent environments.

The Experience API (xAPI) offers a standardized method to capture, store, and share learning experiences across different training modalities, including live simulations, virtual reality/augmented reality, task trainers, real-time physiological monitoring, and assessment platforms. By serving as an interoperability layer, xAPI enables simulation platforms to exchange evidence-aligned training data in a standardized manner, supports cross-platform performance tracking, and facilitates competency-based training strategies.

Building upon prior research demonstrating the viability of integrating learning analytics from multiple platforms using xAPI-enabled content (Presnall, 2020; Salkutsan et al., 2021), this research project leverages the U.S. Army's Generalized Intelligent Framework for Tutoring (GIFT) to address interoperability gaps in virtual and live medical training events. GIFT aggregates diverse training data from multiple sources (virtual reality, task trainers, live exercises), standardizes them into xAPI performance metrics to provide real-time insights into learner progress, and delivers personalized learning pathways based on demonstrated competencies.

In collaboration with local stakeholders, field care competency frameworks aligned with BoldQuest 24 Medical Thread Mission Essential Tasks were developed, with instrumented analytics embedded into the full training cycle, encompassing pre-training, mannequin-based scenarios, virtual reality simulations, and live exercises. GIFT ingests data from various sources, processes them using a domain knowledge file housing relevant competency frameworks, and generates xAPI statements sent to a Learning Record Store (LRS) for retrieval by competency assessment platforms.

In this paper, we will highlight GIFT and xAPI's potential in addressing modularity and interoperability challenges in military medical training, offering a scalable, data-driven solution aligned with Department of Defense modernization priorities, for warfighters receive standardized training that can be effectively scaled across different units.

This paper presents the methodology and results of a field implementation in a military medical context, demonstrating how xAPI and GIFT can be used to unify human performance training data, support competency-based learning, and facilitate real-time performance tracking.

## ABOUT THE AUTHORS

**Biljana Presnall** has extensive experience in eLearning and military training. She led the digital team on a Department of Defense R&D project to mature the operational integration of ADL in multinational exercises (MADLx) and contributed to Annex to NATO ADL Handbook on Advanced Distributed Learning in Exercises. Her research is primarily focused on leveraging advanced data science methodologies within big data environments to develop innovative data strategies and solutions. This includes the application of artificial intelligence and natural language processing techniques to optimize and drive actionable insights. She is currently team lead for US Army DEVCOM Soldier Center's Project STEEL-Rx, field-based validation testing of STEEL-R with exercise planners, observer/trainers, and trainees.

**Dr. Aaron Presnall** is president of the Jefferson Institute. Dr. Presnall is National Chair of the NATO PfP Consortium Advanced Distributed Learning (ADL) Working Group, spearheading multinational cooperation to innovate eLearning and build interoperable, resilient, and agile training capabilities. He led the operational integration of eLearning and Learning and Performance Analytics for 25 years in multinational training events, providing commanders with data-driven insight for decision-making, and training management. He holds a Ph.D. in Politics from the University of Virginia.

**Dr. Benjamin Goldberg** is a senior research scientist at the U.S. Army Combat Capability Development Command – Soldier Center and is co-creator of the Generalized Intelligent Framework for Tutoring (GIFT). Dr. Goldberg is the team lead for a research program focused on the development and evaluation of Training Management Tools for future Army training systems. His research is focused on the application of intelligent tutoring and artificial intelligence techniques to build adaptive training programs that improve performance and accelerate mastery and readiness. Dr. Goldberg has researched adaptive instructional systems for the last 12 years and has been published across several high-impact proceedings. He holds a Ph.D. in Modeling & Simulation from the University of Central Florida.

**HMI Gary McDougall** is a U.S. Navy Hospital Corpsman with deployments to Iraq and Afghanistan. He has contributed to the development, integration, and evaluation of Fleet Marine Force logistics, advanced base concepts, and modernized medical practices to enhance prolonged field care during in-theater operations. His recent work focuses on assessing medical units' readiness to rapidly deploy in support of military operations and crisis response tasks in alignment with published doctrine. He has evaluated team and individual performance across four modes of training: distributed pre-training, mannequin-based test-outs, virtual exposure scenarios, and live instrumented exercises—exploring the feasibility of employing multi-channel audio recording devices during operations. HMI McDougall holds an M.S. in Human Health and Sports Performance from American Military University and an MHA from the University of North Carolina at Wilmington.

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## **BACKGROUND**

Modern military medical training operates in a complex, technology-rich environment that includes simulations, VR/AR platforms, and live field exercises. However, the diversity of these platforms has introduced significant interoperability challenges. Disparate and legacy data standards hinder seamless integration, making it difficult to track competencies across various modalities and impeding the delivery of cohesive, adaptive training (Pettitt & Nortfleet, 2024). These issues are especially critical given the Department of Defense’s (DoD) emphasis on scalable, modular, and data-driven solutions for readiness and modernization (Department of Defense, 2023). To address these gaps, this paper explores the use and benefit of data standards (Hernandez et al., 2022; Naval Air Warfare Center Training Systems Division [NAWCTSD] & Cole Engineering, 2021) with particular attention on the Experience API (xAPI) as a standard for capturing and sharing learning data across multiple environments. Building upon previous research validating xAPI’s utility in capturing cross-platform learning analytics (Presnall & Baker, 2020; Salkutsan et al., 2021), this study integrates the Generalized Intelligent Framework for Tutoring (GIFT) to offer an end-to-end, adaptive training solution capable of translating learner actions into real-time, competency-aligned insights.

This paper presents the methodology and results of a field implementation in a military medical context, demonstrating how xAPI and GIFT can be used to unify human performance training data, support competency-based learning, and facilitate real-time performance tracking.

### **The Experience API (xAPI)**

xAPI is a specification designed to capture a wide range of learning experiences across digital and non-digital platforms. It allows training data—such as learner interactions, performance metrics, and contextual information—to be stored in a Learning Record Store (LRS) in a standardized format (Hernandez et al., 2022). In military medical training, xAPI facilitates cross-platform performance tracking, supporting technologies like VR/AR simulations, mannequin-based scenarios, task trainers, and real-time physiological sensors. It thereby acts as a unifying layer enabling modular integration and evidence-aligned data collection across multiple learning modes and platforms.

### **Generalized Intelligent Framework for Tutoring (GIFT)**

GIFT is a modular, open-source framework developed by the U.S. Army that delivers adaptive tutoring based on domain-specific knowledge models (Sinatra, Goldberg, & Boyce, 2019). In this study, GIFT is used to aggregate learner data from multiple sources—live and virtual—and to process it through a competency framework mapped to mission essential tasks. The system outputs xAPI statements in real-time and enables dynamic human and automated adjustment of instructional strategies. This integration transforms otherwise disconnected data streams into a coherent learner model that supports personalized pathways and performance diagnostics.

### **Tested Competency Framework**

This research integrates competency-based learning, interoperability via xAPI, and adaptive tutoring through GIFT to construct a responsive and modular training environment. At the heart of the system lies a competency framework

developed by the research team to align with BoldQuest 24 Medical Thread Mission Essential Tasks (METs), serving as the reference model for tracking learner progression.

Subject Matter Experts (SMEs) from the 2nd Marine Logistics Group developed the core Training Objectives and associated Mission Essential Task Lists (METLs), serving as the foundation for training evaluation and design. All scenarios and vignettes were designed around METLs derived from the U.S. Marine Corps' Training & Readiness (T&R) manual (Department of the Navy, Headquarters United States Marine Corps, 2018), ensuring relevance to operational readiness.

The conceptual flow includes:

- Mapping each phase of training (pre-training, mannequin, virtual, live) to specific observable human performance competencies.
- Capturing each learner's performance across training phases;
- Generating xAPI statements aligned with defined competencies;
- Processing these statements to generate real-time feedback to support adaptive learning;
- Storing all outcomes in an LRS for retrieval, visualization, and reporting.

This framework ensures not only modularity and scalability but also supports consistent longitudinal tracking of competency development across training environments.

## METHODOLOGY

We targeted the Joint Staff J6 exercise Bold Quest (BQ) and its Medical Thread in particular, to field test and help mature STEEL-R (STE Experiential Learning for Readiness; Goldberg et al., 2021) while providing actionable feedback to PEO STRI's Synthetic Training Environment (STE) modernization program. The STEEL-Rx system (STEEL-R in Multinational Joint Training Exercises) (Presnall, Presnall, & Goldberg, 2024), served as the core architecture for data ingestion and analysis across Live, Virtual, and Constructive (LVC) environments. GIFT processed training data based on a Domain Knowledge File (DKF) linked to the BQ24 Medical Thread Competency Framework. Generated xAPI statements were sent to a Learning Record Store (LRS) and ingested by a competency management server (CaSS) for managing real-time competency assessments.

The methodology follows a multi-phase approach:

- The Pre-training Phase consisted of an eLearning module focused on the Battlefield Assisted Trauma Distributed Observation Kit v4.3 (BATDOK). This module was broken down into actionable sub-tasks, allowing each participant's behavior to be captured via xAPI statements. This phase prepped trainees with necessary patient documentation skills, directly linking to five out of six Training Objectives and related vignettes in the Main Event.
- The Main Event Phase included events covering six Training Objectives that were decomposed into integral tasks and further into sub-tasks to ensure capture of behavioral granularity. Each sub-task was associated with specific observable actions (verbs) designed to be tracked via xAPI statements. Training was conducted under three conditions: Mannequin, Virtual Reality (VR), and Live simulations.

Data collection utilized the STEEL-Rx infrastructure, integrating evidence from a Learning Management System (LMS) and Observer Trainers (OTs) to support summative and formative assessments.

### Competency Mapping and Performance Distribution

Each performance level—across Mannequin, Virtual Reality (VR), and Live training phases—was systematically mapped to the BQ24 Medical Thread Competency Framework, enabling detailed tracking and assessment of medical personnel progression (Vatral et al., 2022). This mapping allowed instructors to trace trainee development across multiple competency domains, including:

- **Core medical tasks**, such as hemorrhage control, patient tracking, tactical field care, airway management, and evacuation procedures;

- **Cognitive-behavioral indicators**, such as situational awareness, stress regulation, prioritization, and decision-making under pressure;
- **Team coordination and communication elements**, such as role clarity, mutual support, shared situational understanding, and task handoffs.

GIFT functioned as the central integration mechanism for performance data. It performed two critical functions: (1) storing live observational data feeds from Observer Trainers and sensors for asynchronous review, and (2) transforming real-time observations into xAPI-compliant statements that could be processed and visualized via the training dashboard.

## IMPLEMENTATION AND FIELD VALIDATION

In the Pretraining Phase, 27 learners took the eLearning course with an average score of 78 out of 100 and a pass rate of 64.52%. A successful completion of the course would indicate “full understanding and operational proficiency of the BATDOK app,” while a lower passing rate would indicate “familiarity with navigation and key features, but deeper understanding may not be demonstrated.” Failure indicates “limited familiarity with navigation and key features.”

A set of actions/steps in the Main Event Phase training was identified to be correlated with pretraining and operational proficiency of BATDOK app:

- Receive & review the TCCC CARD
- Transport Documentation
- Theater Medical Data store and Trauma Logs
- Document treatment
- Prepare documentation for evacuation

The observed performance throughout the Main Event Phase training cycle were systematically monitored and recorded, with GIFT acting as the central integration point for capturing and translating performance data. OTs annotated learner behavior during the exercises via a tablet interface, and this data was ingested by GIFT and structured into standardized xAPI statements. These statements were aligned with the predefined competency framework and transmitted to the Learning Record Store (LRS), where they could be visualized and analyzed in real time.

A custom dashboard—synchronized with both the BQ24 Medical Thread Competency Framework and Training Objectives—was used to track learner progress across all instructional modalities. The dashboard provided a clear depiction of the number of tasks performed below expectations, at expectations, and above expectations, allowing instructors and training supervisors to observe trajectory and growth across the multiple learning platforms and across time at each stage of the BQ chronology.

The above/at/below expectations determinations were made by OTs from the 2MLG who are SMEs in the assessment of medical units’ readiness to rapidly deploy in support of military operations and crisis response tasks in alignment with published doctrine.

Initial performance during the Mannequin phase showed a high frequency of below-expectation task completions, indicating limited proficiency in early-stage procedural execution. However, as trainees progressed into the VR training environment, a marked improvement was observed—below-expectation tasks decreased significantly, while the number of above-expectation completions increased, demonstrating positive adaptation to the training inputs. In the final Live training phase, all core tasks were performed at the expected level, and a comparable number of above-expectation performances were recorded, validating the training progression and demonstrating successful skill transfer to real-world conditions.

This staged improvement suggests that the integrated GIFT-xAPI system not only enabled performance tracking but also supported data-informed competency-based progression, with adaptive reinforcement between each training stage. The following sections provide a detailed breakdown of these results across modalities and individual competencies.

## PERFORMANCE PROGRESSION ACROSS MODALITIES

### Mannequin Phase

During the initial training with the Mannequin, performance data indicated that participants struggled with several subtasks (see Figure 1). Analysis of xAPI statements revealed 38% of the training audience performed “below expectations” (see Figure 2), particularly in areas such as:

- Coordinate evacuation
- Prepare casualties for evacuation
- Submit reports

This phase exposed foundational proficiency gaps in patient documentation using BATDOK and a high correlation to only 11.1% of participants passing the proficiency test in the Pretraining Phase of an eLearning intro to BATDOK course. These analytics from the pretraining phase helped identify areas requiring targeted intervention during the subsequent main training phases.

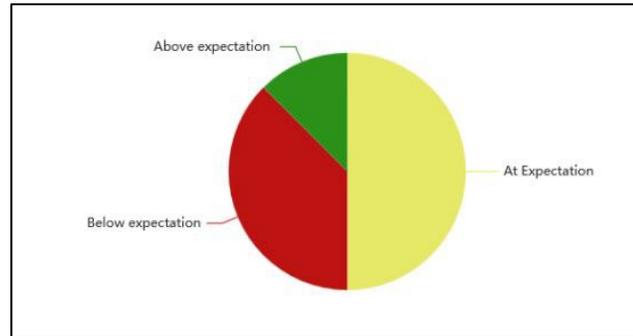


Figure 1. Performance Distribution - Mannequin

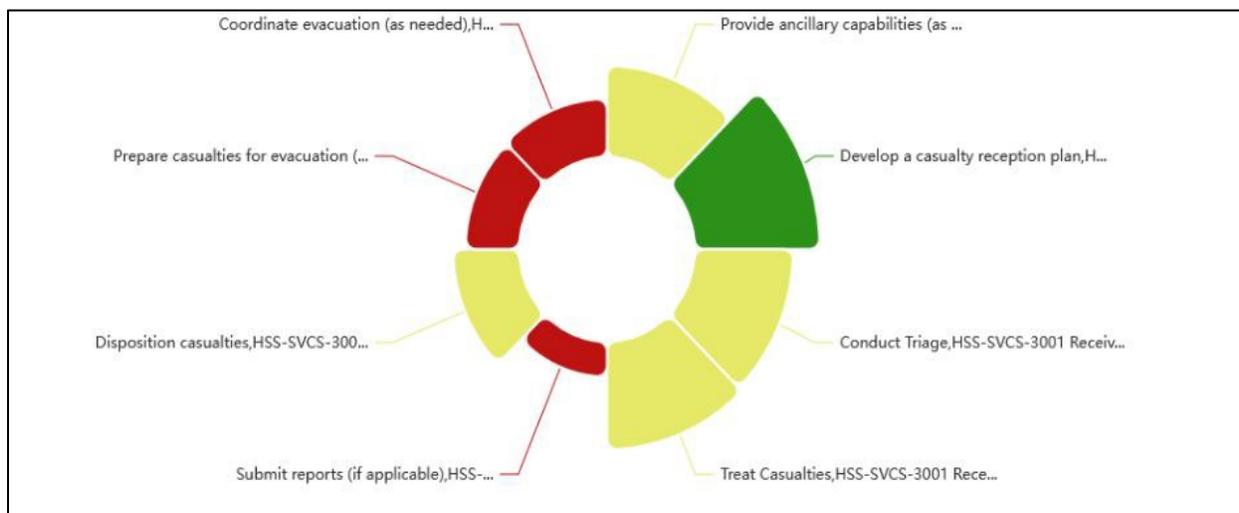


Figure 2. Performance per Task - Mannequin

### Virtual Reality (VR) Phase

In the VR phase, participants demonstrated marked improvement in executing previously underperformed tasks (see Figure 3 and Figure 4). The performance data showed:

- A significant reduction in below-expectations tasks, especially for documentation subtasks.
- A rise in “at expectations” and “above expectations” tasks, indicating growing procedural confidence.
- Improved timing and sequencing in the management of simulated casualty care.

This improvement coincided with the immersive and repeatable nature of VR training, suggesting that the adaptive learning pathways offered through GIFT successfully reinforced targeted competencies.

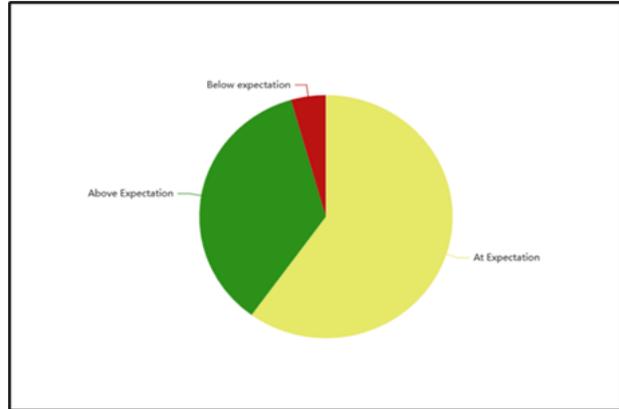


Figure 3. Performance Distribution - VR

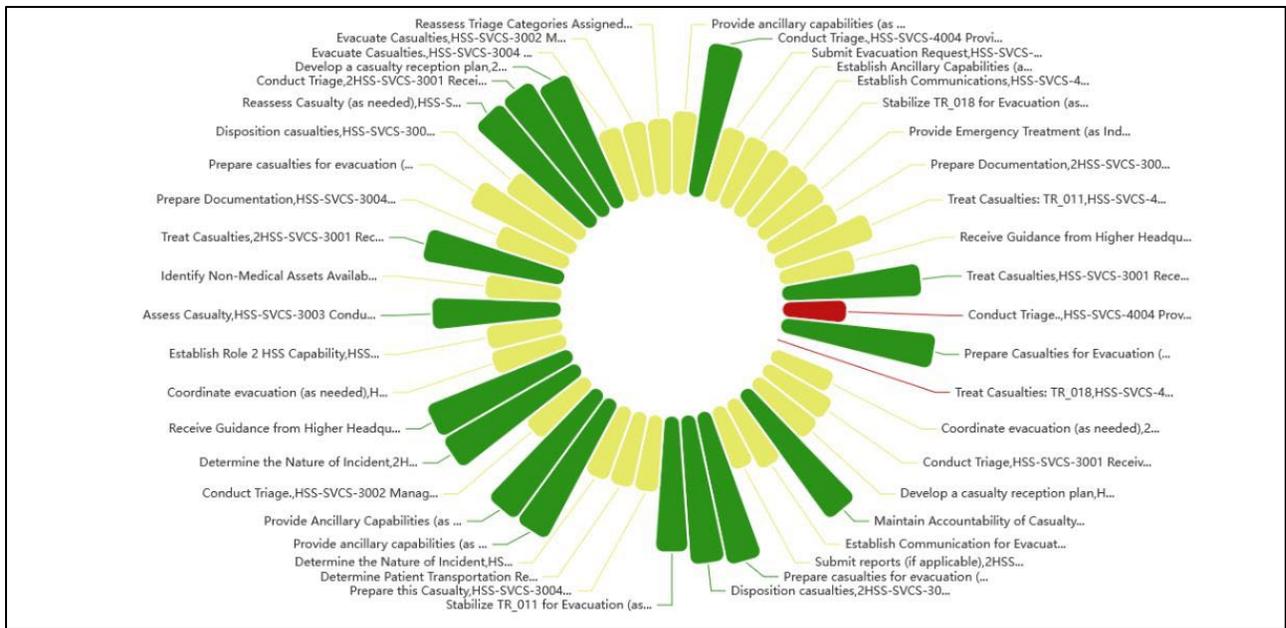


Figure 4. Performance per Task - VR

### Live Phase

In the final Live exercise phase, performance data indicated:

- All core tasks were performed “at expectations” across participants.
- A steady presence of “above expectations” completions, particularly in complex task coordination such as multi-casualty triage and evacuation procedures
- Observer notes (converted into xAPI statements) highlighted learner autonomy, accurate prioritization, and adherence to standard operating procedures.

This convergence of expected and above-expected performance demonstrates the efficacy of the training pipeline, supported by data-driven feedback loops.

Additionally, the consistent quality and precision of task execution across participants suggest that skills acquired during the training were effectively internalized and reliably applied in the live exercise.

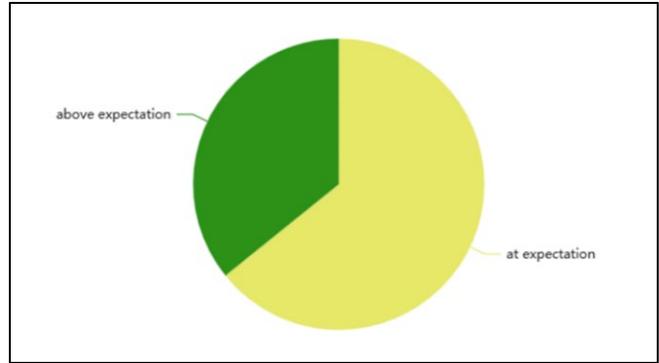


Figure 5. Performance Distribution - LIVE

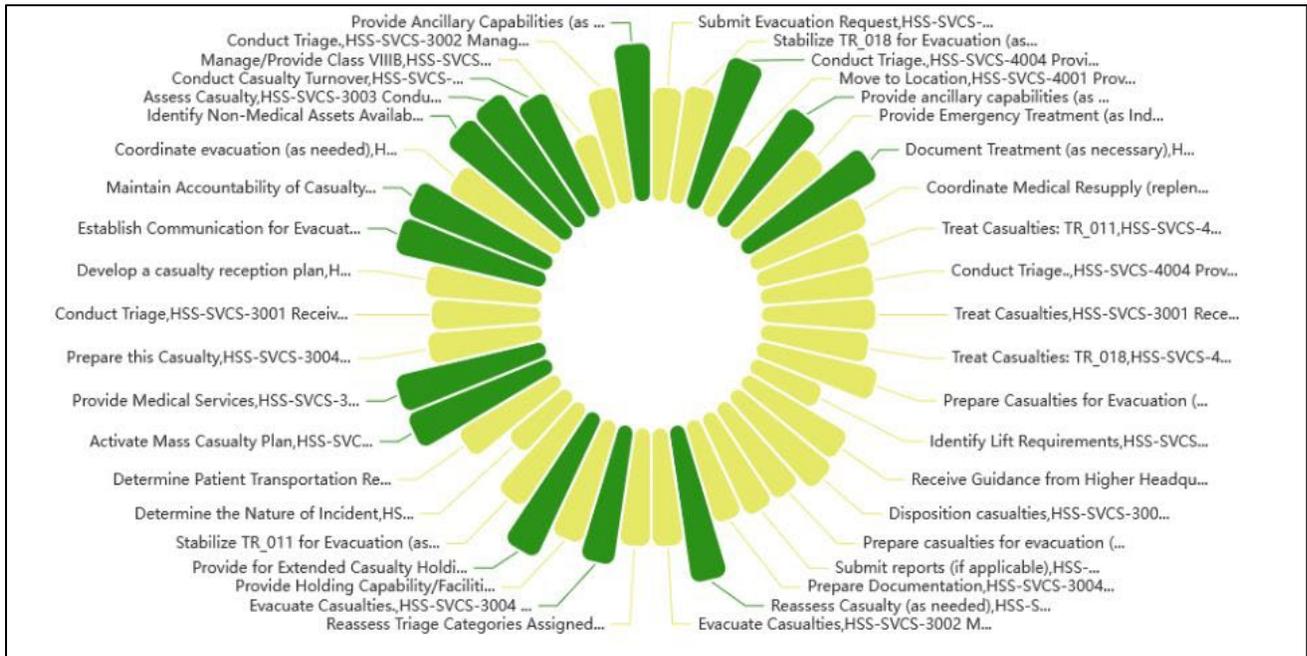


Figure 6. Performance per Task - LIVE

## DISCUSSION

One of the most significant contributions of this case study is the demonstration of how xAPI can bridge persistent interoperability gaps across diverse military training platforms. Traditionally, medical training environments have relied on disconnected systems with limited capacity for data exchange or longitudinal performance tracking. By enabling a unified data schema, xAPI facilitated the seamless capture, aggregation, and analysis of learner interactions across all phases of training. This interoperability was crucial for ensuring that training data remained consistent, transferable, and actionable, regardless of the modality in which it was generated. Moreover, xAPI's open architecture aligns with the Total Learning Architecture (TLA) framework, allowing integration with other Department of Defense (DoD) systems.

GIFT proved to be a vital enabler in real-time performance tracking and feedback generation. Unlike traditional static assessment models, GIFT supported dynamic, context-aware monitoring of both individual and team performance. In field settings such as BQ24, GIFT ingested multimodal data from observer trainers, VR platforms, and live sensors, and transformed it into structured xAPI statements aligned with the competency framework. This capability allowed

for adaptive support, personalized feedback, and enhanced After Action Reviews (AARs), which significantly improved the value of each training iteration. This utilization establishes a consistent assessment strategy across training environments and modalities by leveraging the domain model and associated competency framework (Frank et al., 2010). Importantly, GIFT's modular design enabled it to function reliably even in constrained field conditions—without the need for high-bandwidth or persistent connectivity, making it well-suited for expeditionary and multinational training environments.

The xAPI-enabled dashboard provided a dynamic and intuitive interface for visualizing trainee development. Key insights included:

- A progressive shift from below-expectation performance during the Mannequin phase to consistent and advanced task execution in the VR and Live phases;
- Identification of competency maturation points across phases, with emphasis on:
  - Task comprehension: demonstrated understanding of procedures and decision logic;
  - Mutual trust: increased interdependence and coordinated team response under pressure;
  - Information exchange: improved communication quality and response timing in medical handoffs and triage
- Trend analyses on the frequency and nature of tasks performed above expectations, serving as indicators of performance proficiency and instructional effectiveness.

These competency-aligned insights allowed OTs and command staff to deliver targeted feedback, adjust learning pathways, and make evidence-based updates to training design. More importantly, they offered a structured method to demonstrate and report readiness growth over time—essential for both operational planning and long-term force development.

The findings from this project suggest a clear path forward for future training system design and policy alignment. Competency-based frameworks, when paired with xAPI-enabled systems like GIFT, offer a scalable and modular approach to readiness evaluation. Instructional designers and commanders can use these insights to build adaptive training pipelines that are personalized, data-informed, and directly linked to mission-essential tasks without significant upfront investments. The methodology demonstrated here supports the transition from time-based to performance-based training models, which the DoD and allied partners have increasingly prioritized (National Academies, 2024). Furthermore, the integration of technologies like tablet-based observation tools and real-time dashboards supports a future in which field instructors become active contributors to data-driven learning cycles.

Despite its many strengths, this study also reveals several limitations that warrant consideration. First, while xAPI provides a flexible standard, its effectiveness depends heavily on the quality of statement design and the consistency of verb/object usage across training components. Poorly designed xAPI statements could lead to misalignment with the intended competency framework. Second, while GIFT functioned effectively in this deployment, it requires significant configuration and domain modeling to align with each unique training context. This can present a barrier to rapid adoption in units without technical support. Additionally, the study did not fully address long-term retention or transfer of skills beyond the training event, and future research should investigate how well these competencies persist under operational conditions. Finally, while dashboards offered valuable insight, they still required manual interpretation and synthesis by instructors, suggesting a need for further automation or AI-assisted analytics to reduce cognitive load on training staff.

## CONCLUSION AND FUTURE WORK

This study presents a practical, field-validated model for integrating competency-based training into complex military medical exercises by leveraging the GIFT framework, xAPI, and the STEEL-Rx architecture. It demonstrates how a wide range of training modalities—including eLearning, VR, and live exercises—can be unified through a common data framework and structured competency model to support both training delivery and continuous, evidence-based assessment of knowledge, skills, and behaviors. This approach reinforces the operational value of TLA-aligned systems in enabling scalable, mission-relevant readiness assessments.

A key contribution of this work is the use of GIFT and xAPI to generate meaningful automated feedback, which significantly enhances the value of AARs and offers strong, traceable evidence of training effectiveness. These tools not only support performance tracking but also enable adaptive, scenario-level learning across diverse training environments—extending the model’s utility beyond medical training to broader operational contexts.

The training progression observed from Pretraining to Live Exercises aligns with the revised Bloom’s Taxonomy (Anderson & Krathwohl, 2001), emphasizing a cognitive shift from foundational understanding to complex, real-time problem solving. In the pretraining phase, learners operated primarily at the "remembering" and "understanding" levels—acquiring basic conceptual knowledge such as how to document patients. As training advanced through simulations and VR, participants demonstrated higher-order cognitive engagement, culminating in the creation of adaptive medical solutions under pressure in live scenarios.

To monitor this cognitive development, xAPI was employed to capture fine-grained, time-stamped participant interactions across modalities. These data points were processed by GIFT, aligned with defined competency objectives, and visualized to reveal both individual and team proficiency trajectories. This integration enabled real-time insights into how learners progressed through the cognitive dimensions of the taxonomy, thus offering a data-driven view of learning transformation over the course of training.

Finally, the Bold Quest 24 implementation offers a replicable model for multinational, multiservice training efforts, aligning learning outcomes with mission-essential competencies. By bridging the gap between performance analytics and operational readiness, this study contributes to a broader shift in military training—toward intelligent, scalable, and competency-driven force development.

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