Total Learning Architecture: Moving into the Future

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ABSTRACT

Increasingly, the defense community requires a continuous, adaptive learning enterprise that delivers the right training, education, and just-in-time support, in the right ways and at the right time. The Total Learning Architecture (TLA), now in its second iteration of development, is intended to help meet that vision. The TLA is a set of internet and software specifications being developed to create the interoperability backbone of this future learning ecosystem. The products derived from this project include technical implementation guidelines, Application Programming Interfaces (APIs), middleware, and data model descriptions that help training, education, and personnel management technologies seamlessly communicate through integrated coherent systems.

Spiral-1 of the TLA research and development project focused on developing an initial set of 10 APIs consisting of candidate specifications as well as protocols developed specifically for the initial development cycle. During Spiral-1, community stakeholders provided feedback on the functionality of the written specifications, and end-users (active duty personnel) interacted with a prototype reference implementation created from the specifications. Findings suggested that users could learn effectively through this system and data were efficiently shared between devices and a central learning record store; however, the documentation was overly complex and too idiosyncratic.

Spiral-2 of the TLA research and development project is focused on the identification, incorporation, and evaluation of additional candidate standards and specifications, drawn from recognized international standards and specifications. This paper summarizes the updated state of the TLA Spiral-2 development process, the TLA's current set of recommended specifications, assessment efforts, and ongoing developmental planned.

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INTRODUCTION

Globalization, radical technological advancement, and the corresponding revolution of our social and organizational systems are forcing government and industry leaders to rethink their approaches to talent management. One challenge, for instance, involves the pace of change. The average shelf life for employees' skills is less than five years (LinkedIn Learning, 2018). Combine this with the increasingly broad and complex demands placed upon military personnel, and the result is that today's workforce, whether in uniform or in the board room, must always be learning. At the same time learning technologies are in a leap-ahead moment. Large-scale technology-enabled social networks, increasingly interactive digital content, ubiquitous mobile access, and the rise of learning analytics are driving innovation in education and training. When considered together, these two major trends beg the question: *How do we leverage emerging learning science and learning technologies to meet future talent management needs for the defense community?*

Many initiatives are seeking to address a portion of this question. In the current paper, we discuss the Total Learning Architecture (TLA). The TLA will define a set of technical guidelines, Application Programming Interfaces (APIs), middleware, and data model descriptions that define how training, education, and personnel management technologies "talk" to each other—both syntactically and semantically. The TLA is intended to provide a "plug-and-play" interoperability backbone across these technologies, or, in other words, to characterize and standardize the structure, abstraction, and communication functions of an "internet for learning." The TLA is currently in its second spiral of research and development. This paper describes lessons learned from the first spiral, the current research and development vector, to include the latest set of candidate interoperability specifications under consideration, and assessment procedures for the upcoming empirical testing.

BACKGROUND

What's wrong with the status quo?

A small library of books and reports have now described the growing challenges placed on organizations' talent (Raybourn et al., 2017; Friedman, 2016). In the defense and security domain, for instance, pundits have recognized the escalating requirements for personnel to possess a greater breadth of capabilities, demonstrate them at higher levels of performance, and consistently assimilate new knowledge and skills (Schatz et al., 2015). However, the contemporary DoD learning and development enterprise lacks the effectiveness, efficiency, and responsiveness to meet these requirements. For instance, consider the four limitations outlined below:

> **(1) Stove piped:** Most learning and development experiences (e.g., a classroom course, an e-learning module, a simulator-based scenario, a training exercise, a career-broadening assignment) are disconnected from one another. These events lack cohesion with one-another, which puts the burden of synthesis onto the individuals. Further, each experience typically treats incoming participants as more-or-less similar "blank slates," which limits how effectively the experience can be tailored to individuals' (or teams') characteristics and needs. Ideally, learning and development experiences should be managed as cohesive, career-long continuum. This can be accomplished, in part, by sharing relevant data across learning and development systems and then leveraging these data to manage the system at an enterprise level.

(2) Not Optimized: Most training and education offerings still rely heavily on time-based completion criteria, which often means that top performers waste time while slower learners fail to master all of the content. Some learning experiences have addressed this issue by using mastery learning tactics and adaptive learning techniques (e.g., Kulik & Fletcher 2016); however, even when applied, these advanced methods still only address a stove piped learning episode, such as in a single digital-tutoring course. Ideally, such adaptation should be applied across someone's entire learning and development continuum, at the system-wide level—that is, tailoring an individual's entire learning-and-development trajectory by providing access to the right learning and development experiences, at the right time, and in the right ways across his/her career. This can be accomplished, in part, by applying adaptive learning methods at the "meta" level, i.e., both within *and across* learning and development episodes.

(3) Lack of Robust Data: Today's training, education, and personnel management systems rely on spotty data, which are often locked in unreachable data silos. For instance, when an individual takes an e-learning course, the learning management system will likely only record a "completion" (rather than more detailed performance data). This single datum may, or may not, be integrated into that person's overall learner profile or employee record, and likely, that datum will not be available to personnel management systems. This means that, at the individual level, data-driven personalization of learning and development becomes difficult or impossible. At the organizational level, data-driven management of the system (e.g., evaluating the quality of different course offerings) is also hindered, relying instead upon superficial data (e.g., attendance figures) and subjective feedback to drive decisions. Similarly, at the enterprise level, this means that strategic workforce planning and personnel readiness estimates tend to rely on anecdotal and imprecise information. Ideally, robust learning data collection, aggregation, and analysis would drive the talent management system—enabling us to more effectively manage the larger system, via evidence-based methods, at the local, organizational, and enterprise levels.

(4) Convoluted: It is difficult to trace the impact of personnel's training, education, and developmental experiences on their operational performance and mission outcomes. Correspondingly, the learning and development system tends to lag in its responsiveness to emerging operational requirements. Ideally, more traceable (automated and data-driven) connections between operations and training/education would make the overall enterprise more responsive and accountable. To enable this vision, however, relevant data from across the breadth of talent management systems will need to be aggregated, analyzed, and (at least partially) automated, at the system-wide level.

What's the TLA?

The TLA project is research and development activity, sponsored by the ADL Initiative and conducted in collaboration with stakeholders from across the defense community and from numerous professional standards organizations. The resulting TLA product will be a collection of specifications for accessing and making use of learning-related data. In other words, the TLA is intended to define the data models, interface specifications, centralized software services, communication protocols, and application methods necessary to support interoperability of learning and development data across the talent management enterprise—and to, therefore, help address the four limitations outlined above.

ADL Initiative first introduced the TLA concept in 2013, in a book chapter called, "Learner modeling considerations for a Personalized Assistant for Learning (PAL)." At that time, "TLA" stood for the "Training and Learning Architecture." The name was updated to "Total Learning Architecture" in 2015, to better acknowledge the blurring boundaries between formal and informal training, education, and experience. Throughout 2015 and 2016, contributors grappled with the TLA concept, as evidenced in papers such as Folsom-Kovarik and Raybourn's 2016 I/ITSEC article, "Total Learning Architecture (TLA) Enables Next-generation Learning via Meta-adaptation" and Freed and colleagues' 2017 MODSIM World submission, "More than the sum of their parts: Case study and general approach for integrating learning applications."

Concerted development of the TLA largely began in 2016 and culminated with empirical testing in 2017. Results from the first spiral of development are summarized in Gallagher and colleagues' 2017 I/ITSEC article, "Total Learning Architecture development: A design-based research approach" and detailed in the Institute for Defense Analyses lengthy report, *Bridging the archipelago: An assessment of the Advanced Distributed Learning Initiative's Total Learning Architecture* (Gallagher, Barr, & Turkaly, 2018).

Summary of TLA Spiral-1

The first spiral of TLA research and development helped solidify the TLA conceptual design and culminated in the production of a set of specifications, an initial technical architecture, and a corresponding reference implementation prototype of that architecture. The reference implementation used a suite of 10 initial APIs designed to enable cross-system communication of data about learner characteristics, learning context, competencies, learning activities, adaptation, and system support. (Note, this initial architecture and API set reflect initial and somewhat inexperienced thinking about the TLA, which is now no longer current.)

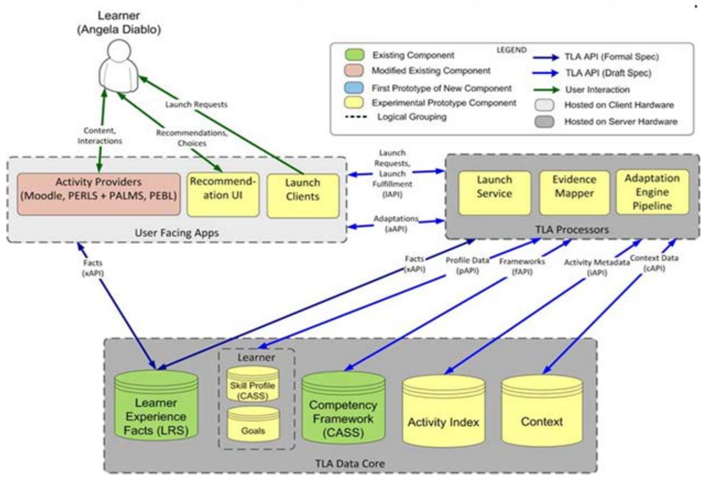

Figure 1. 2017 TLA Architecture
Note: This architectural model is no longer current

Figure 1 depicts the Spiral-1 architecture that was originally designed and, subsequently, developed into a prototype and evaluated. The evaluation process consisted of two parts: First, reactions to the written concepts and specifications, and, second, empirical testing of the reference implementation prototype.

<u>TLA Spiral-1 Specifications Feedback</u>

Broadly speaking, the actual deliverables of the TLA project are documents, such as software standards and implementation specifications. Consequently, TLA developers sought feedback from community stakeholders on the quality and utility of the initial TLA technical documentation. A panel of 54 experts participated in a three-round Delphi-style feedback process (with attrition down to 18 participants for the third round). The Delphi panel provided detailed reactions to the perceived value of the TLA, recommended technical standards to include in it, identified gaps, and made suggestions for increasing the likelihood of its future use (Gallagher & Turkaly, 2018).

The Delphi panel also identified concerns that could impede implementation and adoption. Two primary concerns were the inherent complexity of the architectural design and its use of non-standard specifications. Of the 10 APIs used in the TLA Spiral-1, only the Experience API (xAPI) is an industry standard. (The Institute of Electrical and Electronics Engineers [IEEE] Learning Technology Standards Committee is currently standardizing the xAPI specification; see Blake-Plock et al., 2018). Hence, to facilitate wider adoption, the panel recommended developers more comprehensively evaluate and attempt to integrate existing or emerging learning technology specifications. The Delphi panel also recommended that developers consider mapping more than one standard for the a given purpose. Finally, the Delphi panel underscored the importance of addressing cybersecurity, privacy concerns (e.g., Family Educational Rights and Privacy Act [FERPA] and General Data Protection Regulation [GDPR]), and governance and policy structures early in the development process.

<u>TLA Spiral-1 Empirical Testing</u>

The TLA reference implementation was developed by a cross-organizational team to evaluate the various software services, technical components, and learning activities, all of which exchanged data using the initial set of APIs. The reference implementation was populated with learning content related to cybersecurity and tested with 73 Special Operations at Ft. Bragg, NC in April 2017. Testing consisted of users interacting with the cybersecurity content for 10 hours over four days, with data collected before, during, and after. Learning content was accessed using either a laptop, iPad, or iPod Touch as an iPhone surrogate. An artificial intelligence-based recommender system used data generated by TLA components and activity providers to recommend learning activity choices to each participant based on user competence (Gallagher et al., 2017).

The recommender worked in tandem with an underlying competency management system (Robson & Poltrack, 2017), a Learner Record Store (LRS), and other middleware component services to track individual performance during the cybersecurity course. As a participant navigated through each learning activity, xAPI statements were collected in the LRS. An evidence mapper analyzed these statements and mapped assertions about the learners' abilities against a cybersecurity competency framework that described related knowledge, skills, behaviors, and attitudes. The recommender used this information to deliver learning activity choices to the user.

There were many lessons learned from the testing event that influenced development in spiral-2 and affect the spiral-2 research plan; especially for testing the second instance of the TLA. From a technical perspective, the xAPI was inconsistently implemented across participating organizations, within the different TLA components and between learning activities. This limited the ability to visualize learner progress and did not adequately demonstrate the potential data analytics the TLA can provide. Deciding on the nominal granularity of activity tracking, consistent naming of what is being tracked (i.e., verbs), and a consistent application of these decisions among developers are essential for producing uniform behaviors and meaningful analytics.

Other non-technical lessons centered on the lack of a cohesive user experience across the different devices, platforms, and systems used by the different learning activities. Traditional learning management systems deliver content with a consistent user interface and a common "look and feel" across learning activities. That is not as easily done when knitting disparate sources of content together into a cohesive program of instruction. This challenge is further complicated by the requirement to access learning activities from different computing platforms, operating systems, and browsers. It was observed that learner motivation played a role in whether this issue manifested itself. Some participants were excited about curated open-sourced learning content that met their goals no matter the disparate nature of the user interface while others were not. Additional research may be warranted to help inform the recommender on these, and other learner characteristics that may influence the activities being recommended.

TLA SPIRAL-2: CURRENT R&D VECTOR

Insights from TLA Spiral-1 have informed the second spiral of TLA research and development. Research and development activities for the TLA Spiral-2 fall into four focus areas: refinement of overall concept, significant reworking of the technical architecture and associated technical specifications, development and testing of a subsequent reference implementation, and initial theory-building on the related learning science model.

(1) Refinement of the TLA Conceptual Model

Significant work has gone into refining the overall TLA concept. Figure 2 represents a portion of this. It shows a simplified conceptual model of the different layers of the TLA. This model depicts the refined TLA concept. It reflects the assumptions that the TLA will rely upon existing enterprise infrastructure (e.g., "Network and Facilities") but will also need to be tailored to meet local policies (e.g., "Operational Training and Education [T&E] Domain"). It also acknowledges that Learning Activities and Governance will also affect, and be affected by, the TLA.

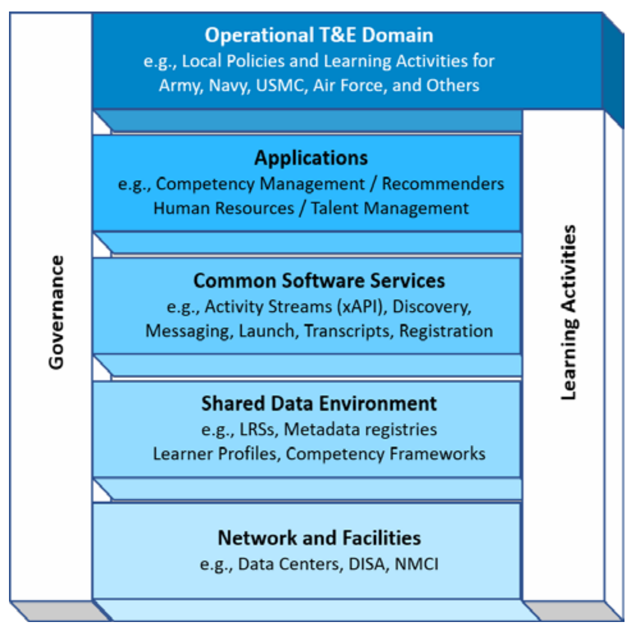

Figure 2. 2018 TLA Conceptual Model: Abstraction Layers

These considerations bound the TLA project; however, the project's developmental efforts focus largely in the centermost layers, that is, concentrating on developing the interfaces needed to share learning-related data broadly across the enterprise, the middleware components required to enable system-wide analyses and automation, and the new capabilities software applications will require to make meaningful use of this data-driven, federation of systems.

(2) Evolution of the TLA Architecture and Specifications

Major efforts in this spiral of development involve revision of the TLA architecture, including its APIs, data models, specifications, and standards. This takes the form of a documentation set, encapsulating architectural diagrams, the relevant specifications and standards, implementation guides, examples and use cases, and developmental and authoring guides. Other research in this area includes policy research for protection of personally identifiable information (Wilkinson et al., 2017), information assurance and the Risk Management Framework (RMF), and the ongoing collection of functional requirements from ADL Initiative stakeholders.

Some of the ongoing research, such as the adaptive privacy specification, is not yet ready for implementation. Figure 3 shows the more mature elements that the developers are integrating for the 2018 reference implementation. This includes components such as an LRS, a competency management system, a recommender, and numerous learning activities.

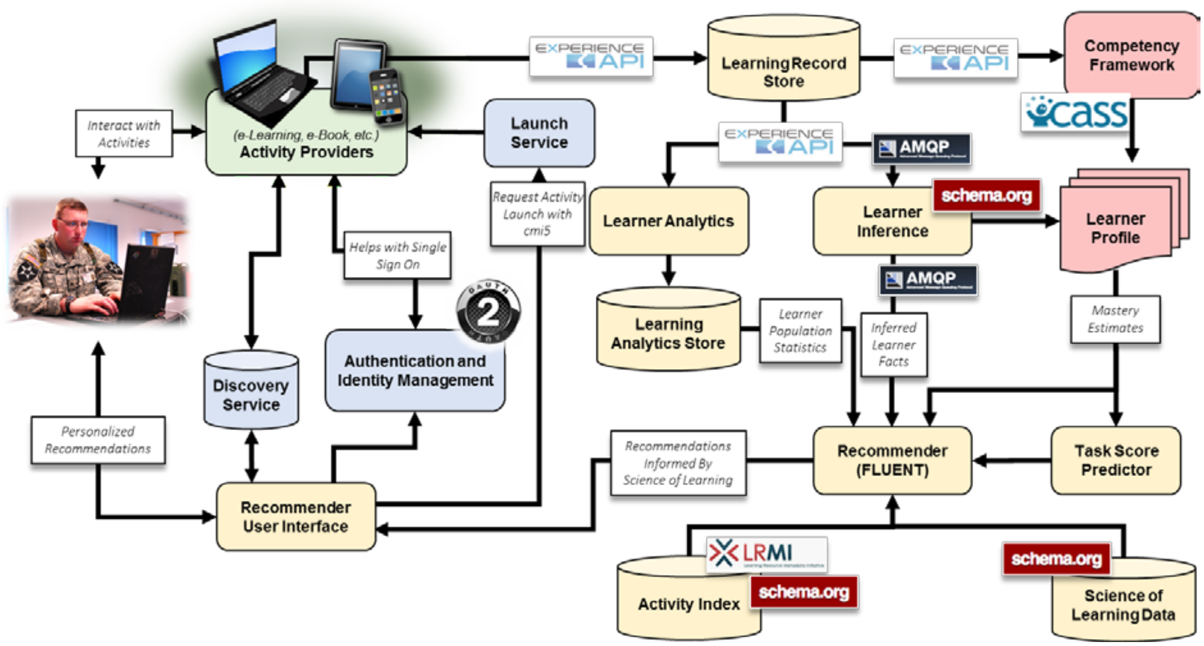

Figure 3. 2018 TLA Reference Implementation Architecture

Activity providers (shown in green) represent the applications that learners and/or instructors interface with; learning activity providers, such as e-learning courseware or an e-book, record learner data via xAPI statements that are streamed to the LRS. Middleware TLA delivery services (shown in blue) include authentication, identity management, content discovery, and launch services. These facilitate the enterprise-wide system access.

Middleware TLA learner performance management services (shown in pink) include the competency framework and learner profile. The Competency and Skills System (CaSS) (Robson & Poltrack, 2017) drives these functions. The CaSS software injects xAPI statements and then makes assertions to transforms the statements into estimated levels of competency for each learner.

Finally, middleware TLA learner tailoring services (shown in orange) include science of learning data (i.e., pedagogical model), an index or registry of leaning activities, learning analytics processes, and an inference engine. The Learning Analytics Store collects information about all users in the system. This data store is used to power the Collaborative Filtering algorithm used inside the recommendation engine—Fast Learning from Unlabeled Episodes for Next-generation Tailoring (FLUENT). Learner inference information is also collected about each individual learner in the system. This information is used to augment the Collaborative Filtering algorithm with content-based filtering that matches content to user characteristics. Learner inference data is also written back to the learner profile that houses competency information. The recommender uses both algorithms to statistically rank each recommendation that is presented to the learner.

It is important to note that some components in the 2018 reference implementation have been consolidated. For example, the learner profile is a component of CaSS, where in an actual implementation, it would typically be a stand-alone capability. Additionally, the activity index is part of FLUENT. Future implementations will further decouple these components.

TLA Spiral-2 Technical Specifications

The interface specifications, communications protocols, and various services used in the first spiral of R&D were mostly hand-coded and not intended for use in future iterations. Those specifications, combined with the different TLA components, supported Spiral-1 concept refinement and testing. However, whenever possible, the hand-coded components and services have been replaced by recognized specifications and/or international standards for learning technologies. For example, where no metadata standard existed previously for identifying learning activities, the Learning Resource Metadata Initiative (LRMI) extensions of schema.org are now being utilized for this purpose.

Table 1 shows a current snapshot of the specifications under consideration for the TLA Spiral-2 reference implementation. Entries within this table do not reflect endorsement by the ADL Initiative and their applications within the TLA may change as the project evolves.

Table 1. TLA Components, Short Descriptions, and Related Specification and Standards

TLA Component	Short Description	Related Standards
Activity Streams	Time-stamped data about learner experiences are tracked across learning activities and throughout the TLA. xAPI is commonly used to track learners' performance, utilization, and context; however, Caliper and HPML can also support.	xAPI, Caliper, HPML
Learner Record Store (LRS)	An LRS stores xAPI statements across learning activities, devices, and platforms. LRSs may be hand-coded as standalone services or integrated into other, larger systems (such as LMSs).	xAPI
Learner Profile	Stored Learner data about competencies, achievements, context, and other learner characteristics that may influence different TLA components. In the TLA Spiral-2 this capability is part of CaSS.	*TBD*
Competency Management System	Competency management system, such as CaSS, provides a common language and framework for describing competencies, resolves different competency frameworks, formalizes the mechanism for collecting evidence of attainment, and manages the lifecycle of learning.	ASN™, CASE™, RDCEO, O*Net
Credential Management System	Credentials are learning artifacts gained through an organization based on merit, such as a professional certification or diploma. A credential management system describes available credentials, enables their authentication, and informs competency assertions.	CDTL
Data Dashboards – Data Analytics and Visualizations	Components that process data to provide insight and reports. In Spiral-1, these are currently connected to the LRS functionality. In future implementations, they will pull data from different systems to analyze disparate data for different categories of users.	xAPI

Activity Registry	An activity registry stores the meta-data related to learning experiences, the relationships among different learning activities, competencies, and other relevant information about each activity. It must also contain the access information and permission to allow access to activities.	LRMI, Dublin Core, LOM
Learning Management System (LMS)	An LMS delivers and manages instructional content, and typically handles student registration, online course administration, and tracking, and assessment of student work.	SCORM, cmi5
Recommendation Engine	A recommendation engine, such as FLUENT, utilizes data from the learner profile, activity registry, and pedagogical model adaptively sequence the delivery of different learning activities and provide optimal learning paths tailored to an individual.	*TBD*

Descriptions of the 2018 candidate specifications or standards listed in Table 1 include:

- **Achievement Standards Network™ (ASN™):** An open metadata specification that provides machine-readable representations of learning objectives and achievement standards.
- **Caliper:** Standard that enables the collection, storage, and transport of learning data; it serves a similar function as xAPI
- **cmi5:** A specification that expands xAPI to support e-learning content launch, authentication, session management, reporting, and course structure; it is essentially a set of "extra rules," or a Profile, for xAPI to support its use with traditional LMS
- **Competencies and Academic Standards Exchange™ (CASE™):** A specification that defines how systems exchange and manage information about learning performance standards and competencies
- **Credential Transparency Description Language (CTDL):** A vocabulary for defining credentialing data and their relationships within those data
- **Dublin Core Metadata:** Dublin Core Metadata set includes vocabulary schemes that that can be used to describe digital (e.g., video, images, web pages) and physical resources (e.g., books)
- **Human Performance Markup Language (HPML):** XML-based schema intended to cover all meaningful aspects of human performance; it can integrate with xAPI, for instance, to add more granular definition to the human performance data descriptions
- **Learning Object Metadata (LOM):** IEEE-recognized open standard that encapsulates a data model, usually encoded in XML, used to describe a learning object and similar digital resources that support learning
- **Learning Resource Metadata Initiative (LRMI):** Collection of properties to describe educational resources, now integrated with the Dublin Core; LMRI builds on, and support extension of, schema.org
- **O*NET Content Model:** Encapsulates the key features of an occupation into a standardized, measurable set of descriptors
- **Reusable Definition of Competency or Educational Objective (RDCEO):** Specification to create common understandings of competencies for learning or careers
- **Shareable Content Reference Model (SCORM):** Collection of specifications and standards that support e-learning interoperability within traditional LMS technologies
- **Schema.org:** Collaborative, community activity with a mission to create, maintain, and promote schemas for structured data on the Internet
- **xAPI:** Software specification that allows learning systems to record, store, and aggregate diverse learning experience data

(3) 2018 TLA Reference Implementation Development and Evaluation

The third focus area for the TLA Spiral-2 is the reference implementation development, testing, and evaluation, to assess the practical functionality of a system built to the given specifications. The reference implementation integrates all the components and specifications described in the previous section. It also incorporates various activity providers, such as traditional e-learning content, a browser-based concept-map assessment application, an e-book, micro-learning activities, a computer-based serious game, and a physical (non-digital) instructor-led learning activity.

<u>TLA Spiral-2 Subject Matter</u>

The TLA is content agnostic; it should be able to equally support any-and-all subject areas. However, to enable empirical testing of the reference implementation, one or more learning topic areas are required. Hence TLA Spiral-2 includes the content and an associated competency framework related to Combat Profiling.

Combat Profiling is defined in the Marine Corps' Combat Hunter program of instruction and the Joint Staff's *Combat Observation and Decision-Making in Irregular and Ambiguous Conflicts* (CODIAC) materials (Schatz, Reitz, Nicholson, & Fautua, 2010). With permission from the Joint Staff J7, the TLA development team integrated the well-defined learning objectives, instructional activities, assessments, and multimedia from the CODIAC package. TLA developers also incorporated the Combat Hunter e-learning course, used normally by the Marine Corps and provided with permission from the Office of Naval Research (Nicholson & Schatz, 2012).

Additional assessments and practical activities were drawn, with permission from the Office of Naval Research, from its Perceptual and Training Systems (PercepTS) project. Notably, this project also provided a taxonomy of perceptual skills (Colombo et al., 2014), which aligned closely with the terminal and enabling learning objectives found in Combat Hunter and CODIAC. This helped inform the TLA Spiral-2 competency framework and learning content metadata.

In sum, approximately 150 different pieces of instructional content and 57 different assessments have been identified for use in the TLA Spiral-2 implementation.

<u>TLA Spiral-2 Assessment Method</u>

Similar to TLA Spiral-1, hands-on testing of the Spiral-2 reference implementation will be conducted in mid-August 2018, in collaboration with the John F. Kennedy Special Warfare Center and School (JFKSWCS), Ft. Bragg, NC, and with participants from its Army Special Warfare Education Group (Airborne) (SWEG(A)). Roughly 60 volunteer active duty personnel from SWEG(A) are expected to interact with the reference implementation for 20 hours over five days. In addition to the learner participants, SWEG(A) Physical Integration Team (PIT) instructors are helping to validate the learning content and assessments.

Seven areas will be assessed:

1. <u>Functionality</u>: The system's features and proposed benefits will be documented, progression of the design from Spiral-1 to Spiral-2 will be recorded, and the reference implementation will be assessed against the defined functional requirements. As participants interact with the system, basic system metrics, user behaviors, and system behavior will be gathered to determine functional performance and whether design goals have been met (e.g. robustness of data analytics, utility of tracking of learner behaviors, and component behaviors relative to the purposes of the APIs in use). Some of the measures used for assessing functionality include counts of types of systems actions taken as a result of corresponding event data; comparisons of recommendations to competency data per user

2. <u>General System -ilities</u>: Related to the functionality assessment, the system's general technical performance will be captured; this includes criteria such as latency, composability, technical reliability, and modularity. System interruptions, downtime, and stress load failures will also be monitored.

3. Specific System -ilities: Similar to the functionality and general system -ilities categories, mentioned above, this item involves documentation and assessment of the idiosyncratic technical performance criteria, such as how varied learners' trajectories are from one another (i.e., system adaptability). Additionally, all TLA components create system logs about operational performance and some components are being instrumented with xAPI statements to help understand how and why different actions occurred. For example, this information could provide valuable insight into how learner inference data was used to make a particular recommendation or why a participant's level of proficiency for a particular competency went down instead of up.
4. Usability (End Users): This assessment includes learners' satisfaction, engagement, and subjective experiences using the system. Data will be captured using existing instruments (i.e., *System Usability Scale* [Brooke, 1996] and *User Experience Questionnaire* [Turner, 2011]).
5. Usability (Developers): This assessment focuses on the satisfaction and experience of those who interact with the system for design and development purposes, such as content developers and instructional designers; this involves both the reference implementation and the viability and quality of its technical documentation. Developers and development stakeholders will evaluate the draft specification to answer whether the TLA V.02 documentation (Architecture and APIs) demonstrates improved viability compared to the previous version and to share their perceptions of the documentation in terms of clarity, functionality and diffusion.
6. Learning Outcomes: Although the transfer of learning is not a focus for this test, the system's learning potential will be assessed to provide a baseline for future experiments. This will be determined primarily by measuring learning gains using a pre/post-test design.
7. Cost Factors: Finally, initial development cost data (to eventually inform return on investment analyses) will be captured from the system designers and developers. Data collection includes both qualitative and quantitative data. For instance, TLA Spiral-2 developers are tracking their hours spent on various activities, to understand the levels of effort required to adequately instrument TLA learning content and to integrate activity providers into the TLA.

(4) 2018 TLA Learning Science

Finally, the TLA Spiral-2 has begun examining new learning science approaches. The TLA vision is for an interconnected learning "ecosystem—an "internet for learning"—that not only facilitates training and education anywhere and anytime, but also helps create the structure needed to optimize talent management. This new paradigm demands a new corresponding new pedagogical (andragogical and heutagogical) model to define *how* it delivers the learning experiences. While this new model is not fully integrated into the Spiral-2 reference implementation, its development is underway, and documented for the new model is expected by the end of the year.

CONCLUSION

Lessons learned and insights gleaned from the TLA Spiral-1 activities (2016-2017) have informed the evolution of the TLA. This year's R&D activities are addressing the need to refine the conceptual design, incorporate recognized specifications and standards while reducing complexity for implementers, and defining a new learning science model for a future where the TLA enables a "learning ecosystem."

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