

COMPETENCY- BASED LEARNING IN 2018

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1. EXECUTIVE SUMMARY

Although technology is front-and-center in today's military operational environment, people are the foundation of our strength. An assessment on the Future Operational Environment¹ by the U.S. Army Training and Doctrine Command (TRADOC G-2) through 2050 underscores the rapid societal changes spurred by breakneck advances in Science and Technology (S&T) and how these changes will impact the art of warfare. Virtually every S&T advance intersects with other technologies, thus increasing the speed of innovation and adoption across the entire S&T portfolio. This convergence allows our adversaries to close the technical gap our military has typically enjoyed and increases the speed of human interaction and cognition required to successfully execute the mission. The human element is paramount. The ability of our personnel to maintain a higher level of creativity, problem-solving, and out-of-the-box thinking is our greatest asset and our biggest differentiator. Therefore, the way we educate and train our personnel directly impacts our future readiness.

Military education and training encompass many different schools, universities, and training programs designed to foster technical, professional, and leadership skills in military service members. Historically, there has been a separation between the education and training communities across the services. Education occurs incrementally and involves grappling with ambiguity while thinking and reflecting about the concepts being learned². Training is linked to readiness and offers opportunities to apply an individual's knowledge, skills, and abilities in a manner that provides immediate feedback and progress measurement. Within the current context, training and education also have different reporting structures, motivations, and logistical requirements such as fuel, personnel, and the access to the appropriate environments or equipment.

Future warfighters must rapidly prepare and adapt to function in an increasingly volatile and complex environment. Where current assessment methods judge knowledge retention for education and skill proficiency for training, there is a significant gap between those metrics and operational readiness and performance. Future force management and readiness metrics must directly link preparations to operations. The class of metrics used to do this is referred to as *competencies* – a measure of how well someone can use their acquired skills and knowledge to complete task(s). To enable the future learning ecosystems, all the ways to assess the ability of a person will need a digital representation. The on-going research on Experience API (xAPI) provides the capability to capture any transaction of learning. The Advanced Distributed Learning Initiative (ADL) is continuing to explore how those xAPI transactions can be trusted as evidence from an authoritative source.

Competency Management Systems (CMS) are the brokers of trust. That trust is based on the validity of evidence, which consists of pre-existing competency frameworks that capture the requirements of a role and is then aligned to frameworks to generate assertions. The ADL Initiative has identified a series of technical capabilities that current learning capabilities will integrate in the future to become variants of the Total Learning Architecture (TLA). The ADL Initiative has invested in CMS prototypes and instantiated a

¹ TRADOC G-2, “*The Operational Environment and the Changing Character of Future Warfare*”, Army Capability Integration Center (ARCIC), Campaign of Learning Technical Report <http://www.arcic.army.mil/App/Documents/The-Operational-Environment-and-the-Changing-Character-of-Future-Warfare.pdf>

² J. Johnson-Freese, “*The Reform of Military Education: Twenty-Five Years Later*” *Orbis*, Volume 56, Number 1, Winter 2012, <http://www.dtic.mil/dtic/tr/fulltext/u2/a570086.pdf>

reference implementation in fiscal year 2018 (FY-18) within a controlled environment. In FY-19 The ADL Initiative will expand its testing of Competency Based Learning (CBL) and its role within the TLA through multiple research projects with the intent for transitioning a capability for Government-wide use. The projects include partnering with the Air Education and Training Command (AETC) to validate CMS within their environment. That effort will involve multiple industry partners and support from a DoD lab.

This report presents an early glimpse into the technical complexities of migrating the DoD towards a competency based educational system in support of the next generation of talent management / talent development to maximize readiness. The report will also provide information on the Competency & Credential work to date by the ADL Initiative, and the work expected in FY-19. Appendix A includes information about concepts and definitions of CBL. It is advised for readers unfamiliar with CBL to review the last section before reading the total document.

2. INTRODUCTION

Personnel readiness to execute missions is at the center of Department of Defense's (DoD) human capital management strategy. Under current practices, the Uniformed Services provide enough training and education (T&E) for personnel to reach a minimum level of proficiency. Credentials are used to codify proficiency for detailing and evaluating personnel. In many cases, these credentials do not expire. However, in high reliability and regulated communities such as nuclear power, healthcare, or aviation, outside accrediting authorities require on-going demonstration of individuals' proficiency.

Within the DoD, entry-level initial training includes formal schools, eLearning courses, and some practical lab work. In the field, service members primarily learn from each other and their own experiences, augmented by performance support and on the job training to maintain their proficiency. Studies show that 70-90% of actual learning happens on the job. However, the methods for capturing individual skills and their contribution to mission success are disconnected and only documented by freeform narratives in evaluation reports. The lack of well-defined performance indicators and performance metrics (competency models), the lack of a fine-grained view into how credentials apply to the work environment, and the lack of ability to correlate/coordinate key performance variables across a career all limit the predictive utility of current T&E systems' contribution to readiness. Historically, only after a disaster or a systemic problem has occurred is the analysis between readiness and T&E performed.

CBL encompasses all the knowledge, skills, attitudes, and other aptitudes, abilities, motivations, and traits (KSAOs) required of a service member in their operational environments. CBL is analogous to Competency Based Education but acknowledges military training as a separate endeavor from education. It provides an approach towards collecting and collating performance and learning data such that time spent in formal T&E is optimized, and the relationship between learning, human performance, and mission effectiveness is made explicit.

The traditional model of education, born in the industrial age with a one-size-fits-all approach for T&E. It places an *instructor* who utilizes a *curriculum* developed by Instructional Systems Designers (ISD) to transmit instructional information to a student. The student undergoes an *assessment* to verify receipt and processing of information. This receipt and processing of information is subject to individualized tailoring by the instructor. If the information loss is minimal (a passing grade is achieved), the student is certified and transferred to the work environment. Learning continues on-the-job through their own experiences, the mentorship of peers, and their familiarity with the challenges of the work environment. However, if those elements are captured at all, it is only in periodic job reviews and personnel evaluations. The curriculum may be updated periodically, but a significant operational failure is often necessary to initiate any significant change in andragogy and/or heutagogy. The gap between learning (training and education) and operational performance induces risk to force readiness and risk to mission. This is depicted in *Figure 1*.

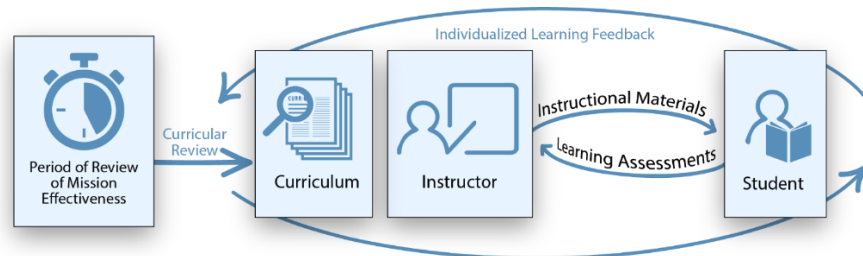


Figure 1. Traditional Training and Education review and update lifecycle

The CBL model views human operators and the systems they interact with as a Joint Cognitive System (JCS)³, where communication occurs between the human operators and the different systems/components (including other operators) they interface with. The requirements for these communication channels are codified in the *competency frameworks* that represent the collection of jobs, tasks, conditions, standards, and other relationships that occur between human operators and system components. These communication channels are mediated by the usability of each system and the experience of the operator. Analysis of these communication channels provide insight into improving the effectiveness of the channels, either by improving usability, or by scheduling learning activities to provide just-in-time training through a feedback mechanism. Thus, learning activities become part of the improvement process between the human operator and the component interface. This relies on the creation of performance indicators and performance measurement of operational systems that sit outside of traditional T&E.

In practice this is a complex web of concepts, as there are many operators, components, and competencies, as well as the different types of data that exist along a continuum of time constants. Migrating toward this method from the current credential-based model requires normalization of human performance data into a trusted and consistently metered data representation. This normalization must, therefore, reduce the complexity of the many-to-many relationships between competency, work, JCS components, metrics, and human operators. The finer grained data, at a much higher sampling rate, however, enables optimization of human performance and concomitant mission effectiveness in a way not currently possible, and only performed after something drastic has happened. This is depicted in *Figure 2*.

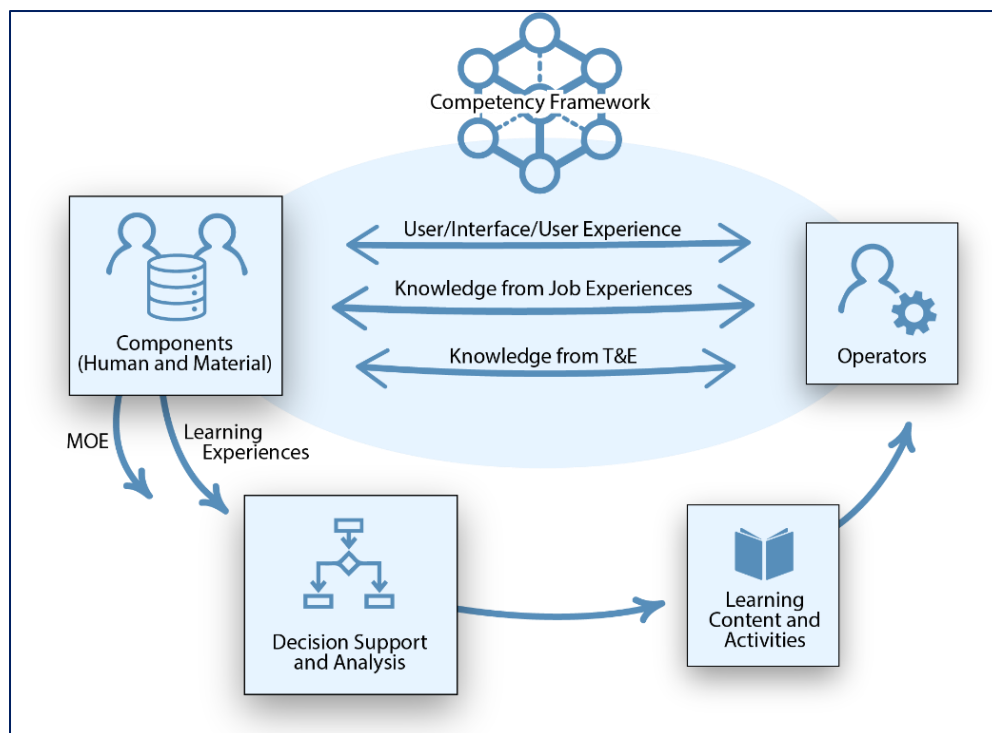


Figure 2. Operators and Components as a Joint Cognitive System - In many of today's organizations, technology has become so pervasive that it functions as a frequent enabler of human performance. By analyzing these channels of communication, we enable learning as a Continuous Feedback System.

³ Woods, D. D. & Hollnagel, E. (2006). *Joint cognitive systems: Patterns in cognitive systems engineering*.

3. COMPETENCY BASED LEARNING AND READINESS

CBL promotes the concept of a competency framework comprised of competency objects that represent the relationship among the KSAOs of an individual performing a job. As shown in **Figure 3**, a competency framework is a collection of competencies that provide clarification about successful performance in different roles at different levels throughout the organization. A competency framework organizes the competencies needed to perform successfully in a work setting, such as a job, occupation, or industry. The competency framework can be used as a resource for developing curriculum and selecting training materials, identifying licensure and certification requirements, writing job descriptions, recruiting and hiring workers, and evaluating employee performance.

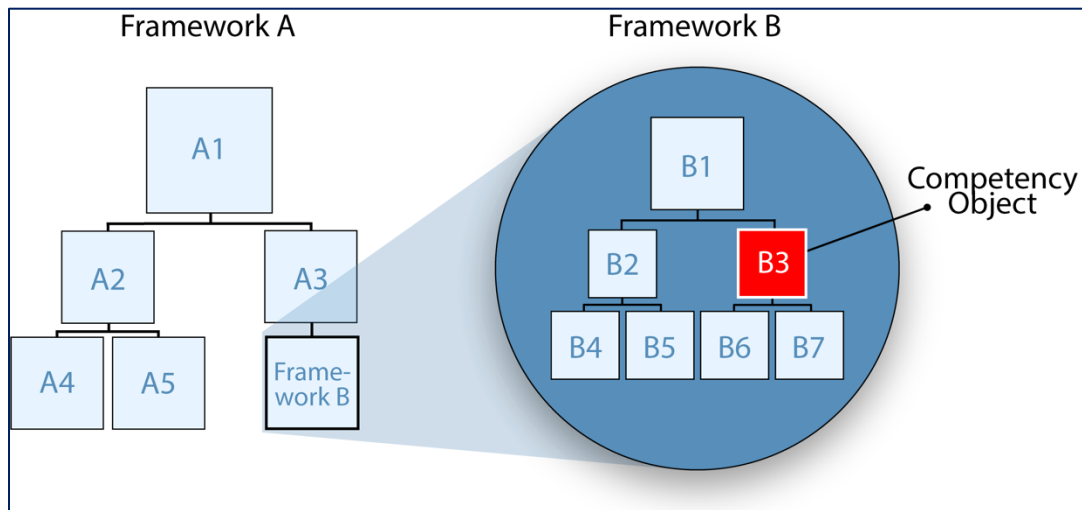


Figure 3. Competency Frameworks - A competency framework is a representation of the competencies required for a certain role within an organization. They are comprised of competencies and sub-competencies that can be shared across frameworks. Although shown as a hierarchy above, they are not necessarily linear.

In the industrial model, KSAOs are substituted with Learning Objectives which are taught in a Program of Instruction (POI). The POI typically includes several formative assessments, followed by a summative assessment (whether in test form or as a subjective evaluation by a qualified person) to measure learning transfer from the course to the student. The system is based on trust in the observers and instructors to properly evaluate and capture records. Once the final grades have been tallied, many details are lost. Moreover, the completion of the POI is often used to justify the conferral of a credential, after which point, the credential is the only record on file.⁴ Accreditation is a key component of trust in the education field's interpretation of competency. Accrediting bodies engender trust through open processes and an incentive structure that ties high standards to profit or growth.

In the CBL model, the competency frameworks establish a clear linkage between individual KSAOs and organizational performance (e.g., Talent Management / Talent Development). These frameworks, in turn, are built on trust. Assertions against the framework are only as valid as the evidence that supports them. The data strategy for every competency must align the observable performance indicators for each of the

⁴ Regulations typically require archival of grades to provide transcripts, but this information is neither portable with the servicemember, or readily available.

KSAOs encapsulated into each competency. Some evidence will be derived from T&E systems, while the large preponderance of evidence will likely reside in the operational environment. Even though a lot of this data already exists, the availability of this data across the DoD enterprise is limited due to legacy technology architectures and organizational stovepipes of information. A coordinated data architecture and digital transformation process must realign these organizational firewalls to be successful in implementing CBL.

Digital competencies are the currency of human performance. Therefore, assertions must be based on a trusted, evidentiary record that documents the situational context of the interactions taken by the human operator, and the state of the systems being interacted with in the workplace. A collection of assertions provides an estimation of individuals' capability to meet mission, which are validated against operational experience.

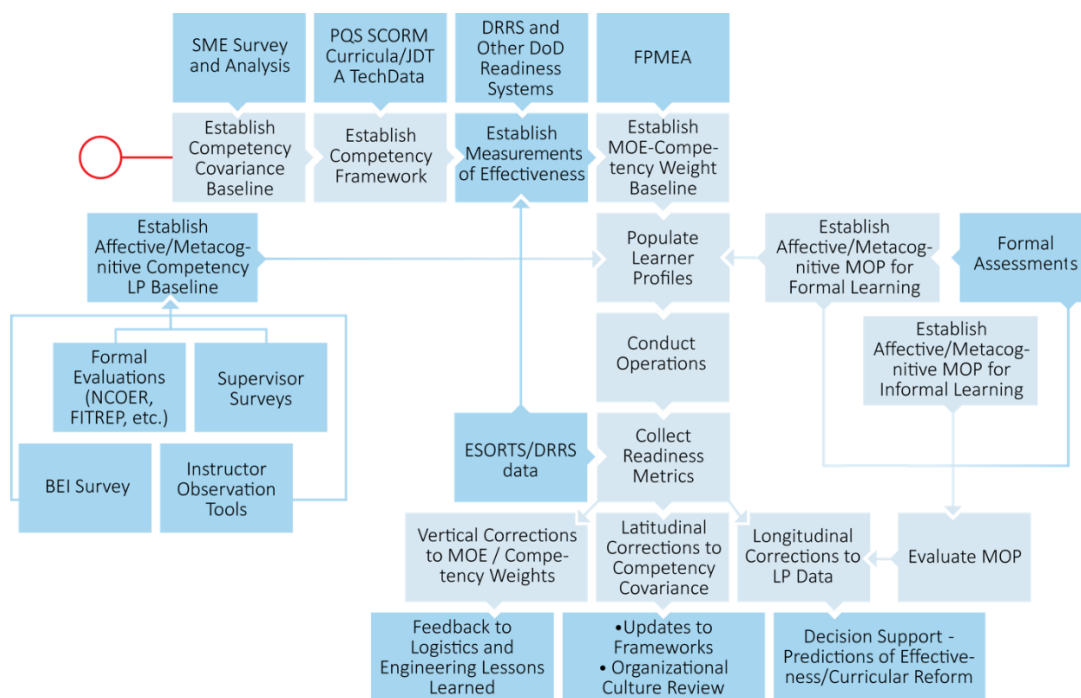


Figure 4. The Path to CBL - Stated simply, evidence of performance from trusted agents provides assertion of competency. Competencies evaluated against Operational data inform inferences of the relationships (weights) between competency and readiness, such that, over time, we can measure the competencies of an organization and make reliable predictions of its state of readiness.

Over the past decade, the DoD has made rebuilding the readiness of the military force one of their priorities and has outlined this priority in a key strategic guidance document. However, no comprehensive plan has been established to coordinate this effort⁵. Currently, the policy of blind trust in credentials introduces risk, because credentials obfuscate the actual state of a person's competency. Recent disasters in the 7th Fleet⁶ have been attributed to lack of training, inadequate practice while on-board, and lack of sleep among a litany of other issues. These causes were driven by cultural failings to accurately report readiness. These cultural issues were intensified, since there were no systems in place that shared the actual measurements of performance and state of the ships that were not dependent on human interpretation.

⁵ Military Readiness GAO-16-841, p.6 <https://www.gao.gov/assets/680/679556.pdf>

⁶ 7th Fleet GAO report <https://www.gao.gov/assets/700/695911.pdf>

Through DoDI 1322.26, the DoD recognizes xAPI as the vehicle for capturing human performance data from any system. By extending the capture of data from T&E systems to operational systems, CBL can be used to evaluate round-trip estimates of readiness. **Figure 4** provides a theoretical path to reaching CBL in the DoD. This requires a radical rethinking of the data silos present by our current organization, which is a problem common to any digital transformation. By gathering and correlating these data sources, we can build towards a predictive system for readiness. This predictive system can also provide early demand signals for the overall *human capital supply chain management* problem of military personnel.

4. COMPETENCIES IN THE TOTAL LEARNING ARCHITECTURE (TLA)

Within the context of the TLA, the Activity Stream(s) stored in the Learning Record Store (LRS) provide the evidence upon which *competency assertions* are made. The Competency and Skills System (CaSS) is a TLA component that generates rich and traceable data about learning experiences and how they relate to skill proficiency, ultimately resulting in a certified set of credentials for the associated KSAOs. Each role in an organization is required to perform a set of jobs. Each job has its own set of competencies needed to perform the job effectively. By defining these competencies, policy can enable a standardized approach to performance that is clear and accessible to everyone within an organization.

Competency frameworks are expressions of the work environment. Many factors that affect the nature of each framework include the native language of its learners, goals of the assessments, availability of software engineering support, and the role of accrediting bodies. All these factors drive customization, and more importantly creativity in this space. CaSS addresses a reality of CBL where organizations will develop their own frameworks and may never converge on a single standard. For example, this is evident in how nuclear power personnel and aviation personnel are certified for their work. Even though they work in the same service and on the same platform, it is unlikely that all facets of their work can be aligned under one competency framework.

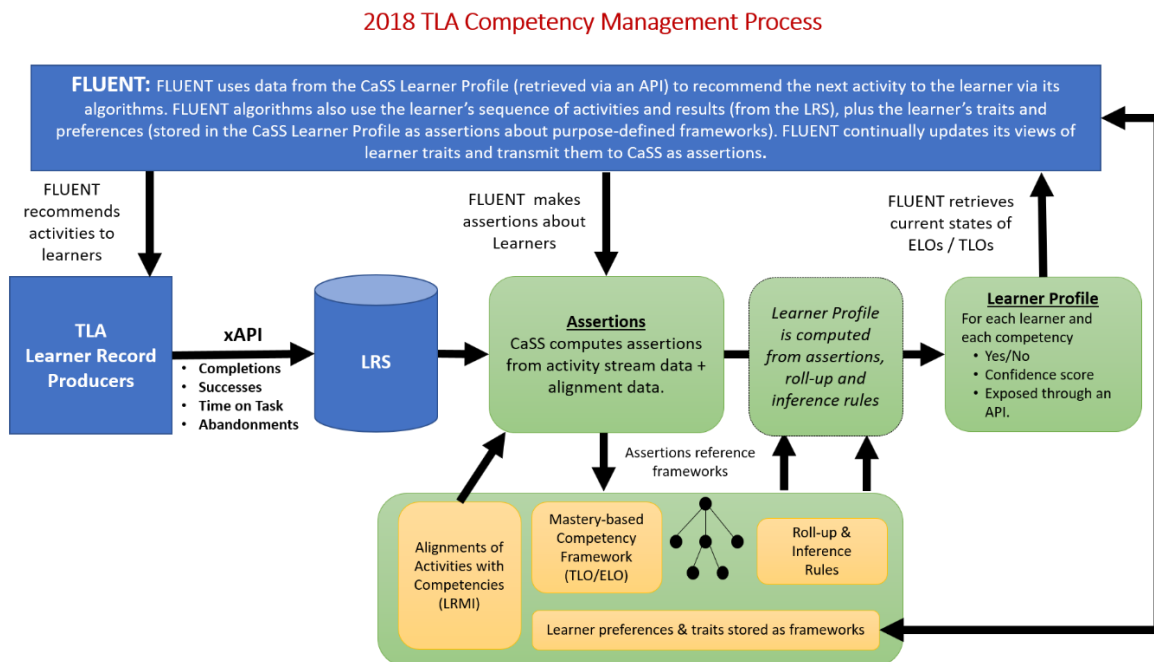


Figure 5. Competency and Skills System (CaSS) – The 2018 TLA Reference Implementation used CaSS to create, manage, and share information about competencies with other TLA components.

CaSS ingests multiple different competency frameworks and aligns the different attributes about each competency to provide a common language and translation method for defining competencies, the associated evidence of attainment, and the different relationships that intertwine with each competency. It implements a well-defined set of attributes and rule structures based on [Schema.org](https://schema.org) terms that are encapsulated using linked data. CaSS also stores assertions and evidence over time to record the progression of a learner pursuing competencies within a framework. Key to establishing assertions of competency from an Activity Stream is the reconciliation between the *Actor* in an xAPI statement (stored in an LRS) and a persistent Learner Profile.

As shown in **Figure 5**, the 2018 TLA reference implementation, CaSS pulls xAPI statements from the LRS and checks the *Verb* to determine whether the statement claims any evidence of competency. For statements that infer competency, the `ObjectID` from the xAPI statement is compared to the Activity Registry to determine which competencies a statement is evidencing. For 2018, all content was treated the same and incremental increases in competency were assigned for each completed activity. The 2019 reference implementation will include the “weighting” of evidence based on the metadata stored in the Activity Registry that describes each activity. However, this approach was not supported by the recommender.

The primary output from CaSS is a series of Mastery Estimates for an individual over time. This data is managed within the competency service layer and written to a machine-readable learner profile that other TLA systems can access. The CaSS project also investigated blockchain technologies for managing some elements of competencies. A proof of concept was deployed to the Ethereum Blockchain to validate that assertions of competency into a Learner Profile from CaSS can be recorded in perpetuity on a Blockchain.

4.1 Enabling Complex Systems with Competency

This section provides a theoretical scale for measuring the complexity of a TLA implementation. The five TLA adoption levels shown in **Figure 6** build upon the basic eLearning and classroom pipelines commonly in use today. This scale is focused on architecture and does not prescribe how implementations are instantiated. The determinations throughout this paper are based on the critical role CBL plays in maturing any learning ecosystem to the point of providing adaptive and intelligent capabilities to its learners.

Current training and education environments include a wide range of learning activities that are not fully connected. Learning management systems (LMS) and other digital technologies (e.g. simulations, hand-held learning devices) supplement the student-teacher relationship. Most instruction is linear, composed of terminal and enabling learning objectives (or equivalents), and planned in terms of a constrained schedule for student attainment of minimum standard to satisfy the award of credentials.

As a learning system implementation matures to the first TLA adoption level, the introduction of xAPI and an LRS increases the richness of analysis and decision support. Activity tracking data (e.g., xAPI) pulls a myriad of performance data out of any range of learning activities and aggregates the data for analysis using commercially available tools. The xAPI and LRS can normalize classroom data with data collected from an LMS, simulators, on-the-job work experiences, or any other network-connected Learning Record Provider (LRP) into a data store that is accessible for review.

TLA adoption level 2 incorporates dashboard visualizations tailored to specific roles within the TLA. Instructors, students, instructional designers, administrators, and leaders see performance data and have better understanding of past performance when making decisions. This affords instructors the opportunity to facilitate interventions based on data from outside traditional classroom or eLearning environments.

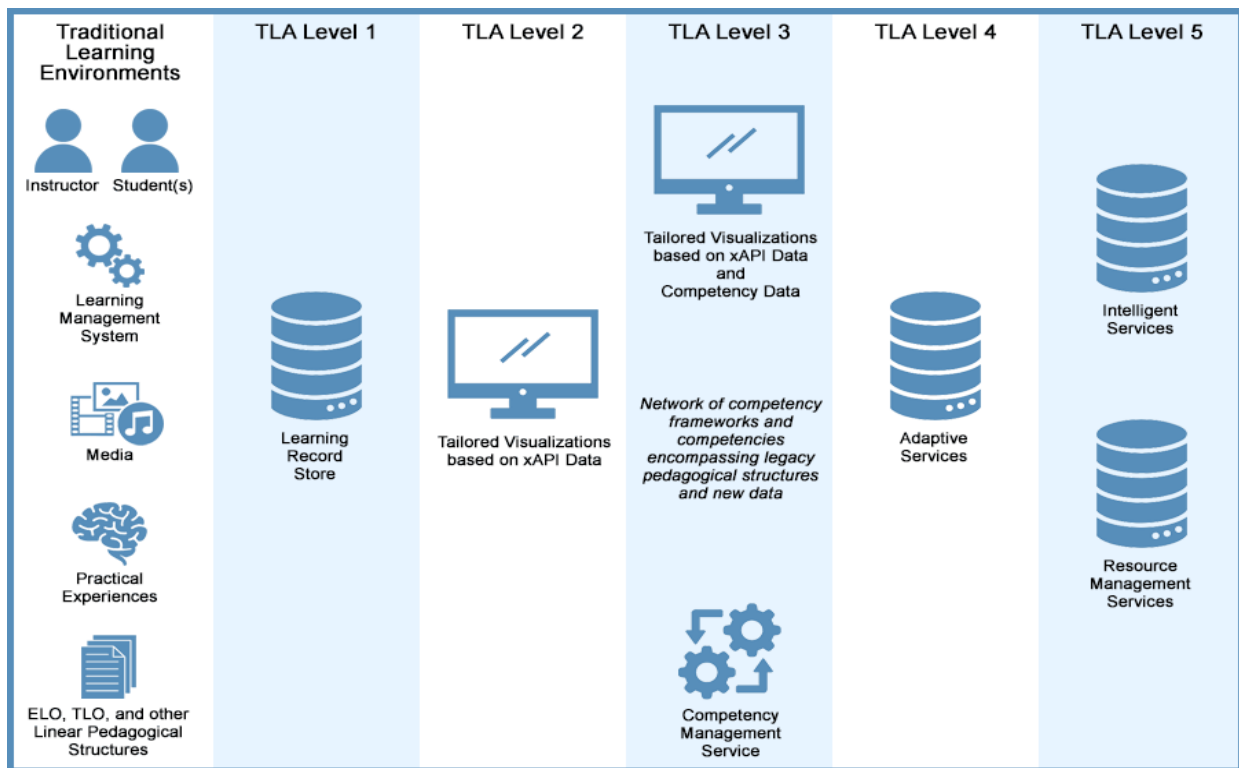


Figure 6. TLA Services to support Competencies and Credentials - Within the TLA, an activity stream (xAPI) captures what the user is doing and which learning activity the learner's experience is being tracked. The xAPI statements record predefined experiences related to learning within each learning activity. These statements are stored in an LRS as shown in Level 1. This empowers detailed analytics based on a learner's performance across numerous LRSs as shown in Level 2. The TLA can also incorporate a competency management capability as shown in Level 3. This must be populated with a complete framework that describes the role and requirements of a learner, retains enough data about their progression, and includes processes or functions to ensure that included data can be trusted. As more data are collected about learners, learning activities, and competencies, the TLA is afforded the ability to adapt the sequencing and delivery of different, yet related learning experiences that are tailored to the needs of everyone. Eventually, the TLA will tie into other services and systems (e.g., Resource Management Systems) to help determine the availability of different learning activities outside the traditional boundaries of Distributed Learning (DL). This enables a data architecture that supports lifelong learning.

The promise of TLA adoption level 3 is using this information to augment the instructional design of educational and workplace interventions based on pursuit of competency. Competency management allows for additional customization of the learner path, and most importantly, learners are freed from the linear, schedule-constrained, course-centric model. Within a CBL system, a learner can benefit from learning compression – completing course modules versus entire courses, focusing specifically on the elements of competencies they are lacking.

The TLA adoption level 4 includes additional data richness in the competency and activity-tracking services to enable adaptation. Adaptation services provide more tailored experiences for a learner and the ability for the TLA to optimize its approaches across a student population. Adaptation includes anything from content recommenders to intelligent systems or intelligent tutors. A TLA adoption level 5 fully leverages machine learning, providing integrated macro- and micro-adaptation for planning a continuous-learning path, but also for optimizing training resources. In practice, these will likely remain manual activities, but the use of the integrated data strategy in the lower level implementations should greatly enhance the Electronic Decision Support Systems (EDSS) available to aid in those decisions.

4.2 Authoritative Sources and Authoritative Storage

Authoritative Sources and Authoritative Storage as formal designations of a given capability are seen in DoD network architectures today. Systems or agents that have these titles are critical components of trusted, actionable data moving throughout the DoD. Authoritative Sources are considered the trusted reference system that generates specific data. Authoritative Storage is the location where a record is held in reference to an Authoritative Source. The Naval Information Application Product Suite (NIAPS)⁷, which is a collection of tools that support the Fleet at sea, is a good example of such a record. On-board, the NIAPS hosted applications are the authoritative source and storage point for the local Commander. They may have information that is more up to date than the record available to the US Navy on shore. This reality does not make a NIAPS server on-board authoritative beyond the ship. Those servers are subject to bandwidth and operational restrictions that makes their updates unpredictable. The US Navy views the NIAPS servers on shore as authoritative source and storage point since they are the most-timely and accurate in respect to all ships using NIAPS.

4.3 How Competency Enables Complex Systems

At TLA adoption level 3, the presence of a Competency Management System represents a paradigm shift within an organization and its learning ecosystem. The use of competency frameworks allow an organization to accept non-structured data into their estimation of human performance. To do this, business process, instructional design, systems acquisition and, most importantly, culture must change. Instructional design within the DoD tends to follow the processes identified in MILHDBK 29612-2A Instructional Systems Development/Systems Approach to Training. This handbook enables procuring and maintaining Shareable Content Object Reference Model (SCORM) compliant distributed learning. Across DoD, the ability to capture learner data equally across all systems does not exist. At level 3, ISDs within the DoD will require new standards, processes, and guidance to align their content within more complex systems.

ISDs will also require processes and tools to build frameworks and align activities within the work environment that can generate assertions. The ISDs must then be backed by policy that will allow them to ensure these assertions are met within the engineered systems. The current Systems Engineering Technical Review (SETR)⁸ processes exist to meet functional requirements for training systems and operational systems. SETR must include additional processes and support to look at driving a competency framework through human interactions with systems. Functional Requirements for Competency is a new concept to SETR but must be addressed. xAPI can capture the activities of Subject Matter Experts (SMEs) and learners, but systems will need to be constructed that can leverage that data during their total life-cycle.

The current Defense acquisition process fails to populate all the data available regarding human performance into a common data layer within its networks. Weapon systems process tremendous amounts of data and depend on the interaction of dozens of personnel. The potential magnitude of evidence that work systems can generate can drive competency frameworks to become true models of human performance. To move DoD communities to a TLA adoption level 4, analysis is required to identify the barriers blocking the instrumenting of all systems to generate performance data.

⁷ NIAPS https://www.public.navy.mil/spawar/NAVY311/Pages/NIAPS_Info_Center_FAQs-Basics.html#Q1

⁸ <https://www.dau.mil/cop/se/DAU%20Sponsored%20Documents/SETR%20Process%20Handbook%20v1.0%2020150206.pdf>

4.4 Moving from Level 2 to Level 4 of the TLA

As envisioned, each school, simulator system, or other collection of learning activities will establish its own LRS. The xAPI specification enables federated LRSs, which results in managed authoritative data about each learner. Each unique LRS, through permissions, enables a trusted relationship that hold statements about an individual's performance that can roll up into an aggregated learner profile as shown in **Figure 7**. The *transactional layer* represents all xAPI data. This xAPI data either promulgates to an authoritative LRS or remains within local systems. The concept of internal vs external statements is centered on how critical the statements are to capturing training records for credentials. Some LRSs and systems may be allowed to issue assertions that provide credentials to users.

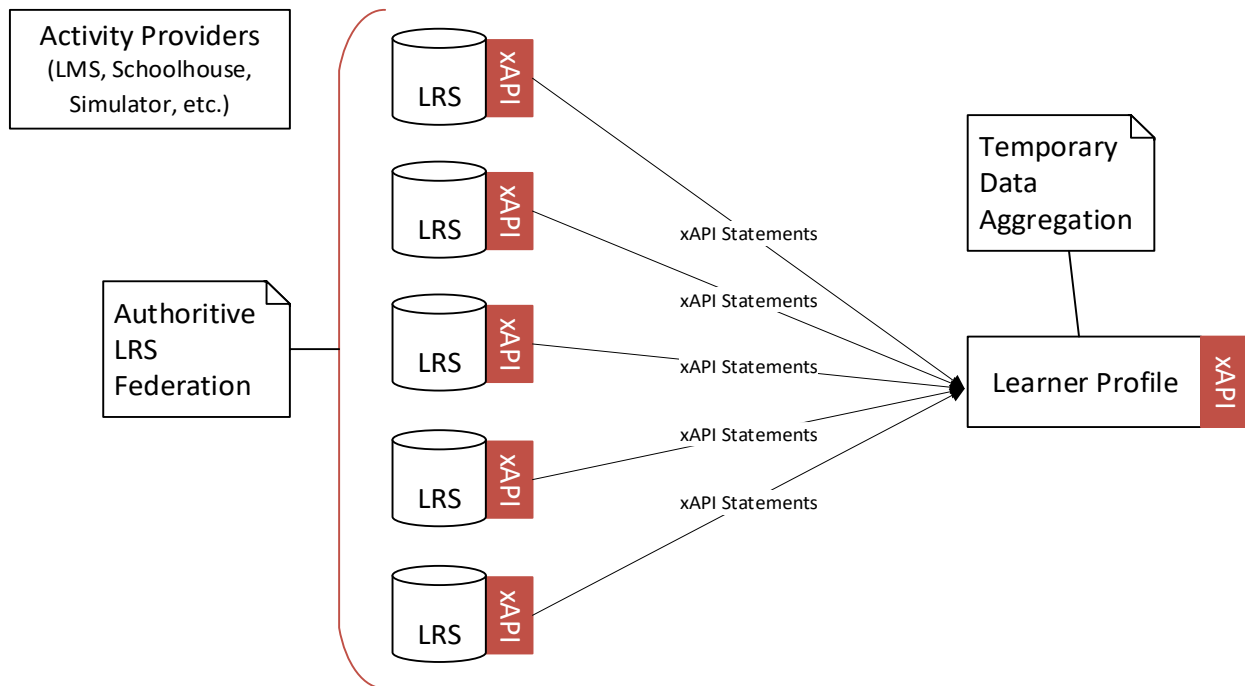


Figure 7. TLA Adoption Level 2: Federation of LRS Supporting a Learner Profile - xAPI statements are captured in an LRS that can be associated with any learning activity, or collection of activities. These are federated data sources that can be rolled up into different levels of granularity.

Each of the connected LRSs in **Figure 7** collect data at varying levels of granularity. A flight simulator may collect fine-grained statements about the learner inside a simulated scenario, while an LRS associated with a school may track the student at a much higher granularity (e.g., formative/summative evaluations, transcripts). In this capacity, all learning records are preserved in the system in which they are created.

For a competency management service to be instantiated within the TLA, another LRS must exist that collects statements rolled up from the transactional layer. This is due to the Kafka streaming architecture set up for the 2019 TLA reference implementation. As shown in **Figure 8**, each LRS at the learning transaction layer will stream statements into a common LRS. The competency management service does not care about every statement a learning system makes about the learner. Instead, the CMS is more interested in when key events happen that assert something important about the learner. Assertion statements are captured in a different federation of LRSs that preserve competency data. Ideally, this arrangement would allow legacy systems that do not align to competency frameworks (legacy LMS, simulators, and observed human performance) to change through attrition.

In the future, all systems used to provide evidence of competency, both T&E and operational, may have an LRS, business logic, and authoritative data sources identified. The learner profile service will draw on multiple, authoritative sources to present a snapshot what an individual knows at any given point in time. It can also act as a source for other systems to base decisions from such as simple adaptive systems and scheduling systems. It can act as the authoritative source for multiple authoritative storage points under this model. This would afford the DoD a trusted source but allow the services to maintain authority over their own data.

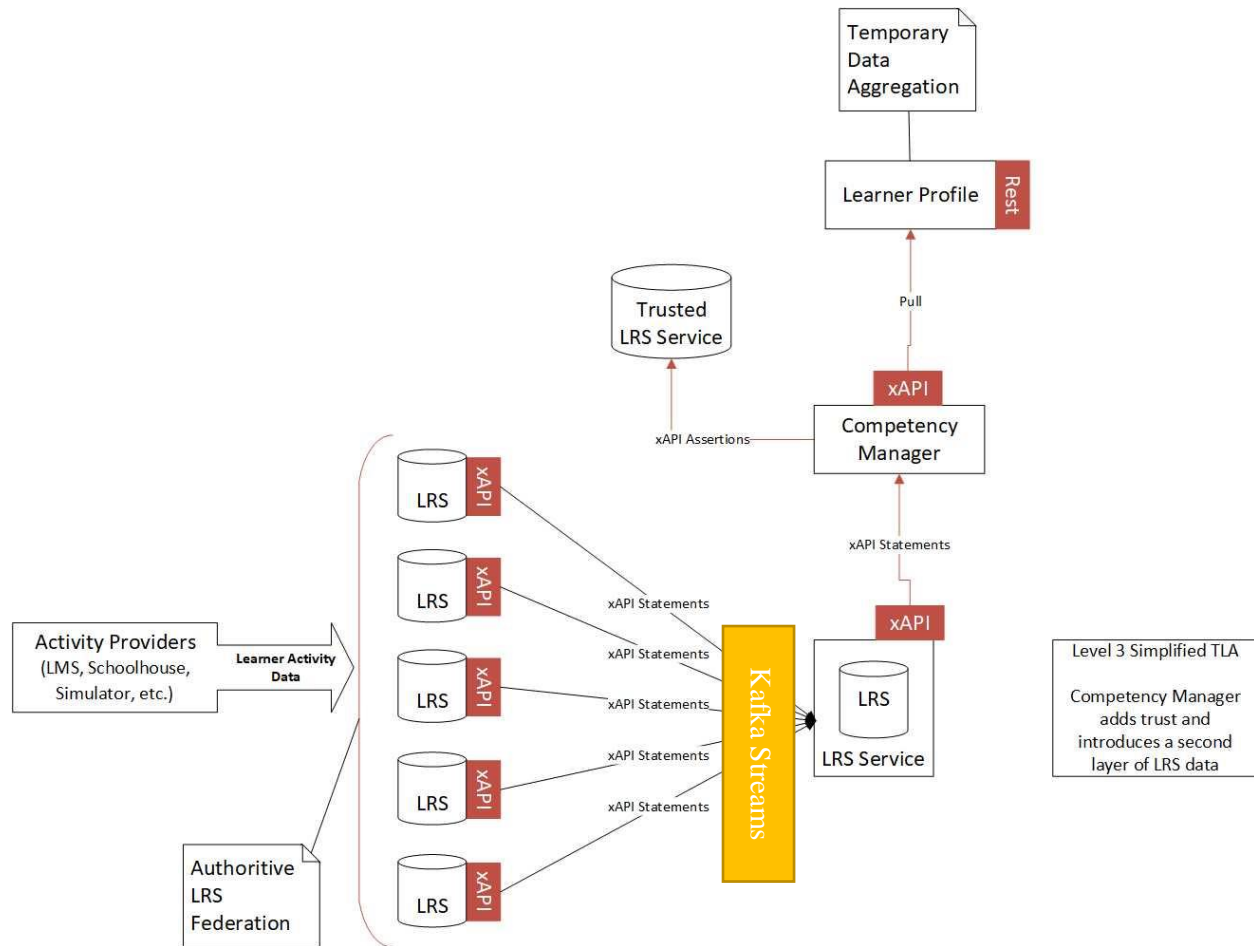


Figure 8. Adding Competency Management - The addition of a competency management system enables assertions against specific competencies held inside any number of competency frameworks. Assertions are made from the federated LRS data that collect performance information from T&E and operational systems.

Figure 8 shows the connection from the transactional LRSs sending statements through the Kafka stream to an LRS that aggregates statements from multiple learning activities and feeds them to a CMS. The CMS, in turn, infers competence and writes the mastery estimates to the learner profile. In the learning ecosystem, legacy authoritative LRSs would not be accessed by the learner profile once this level of maturity is reached. The CMS can still capture and trust appropriate legacy asserted xAPI statements but would also scan its other contents and compare this to trusted frameworks. At scale, it is important to preserve interoperability between LRS federations, competency frameworks, and learner profiles.

This level of TLA adoption provides a level of maturity where complex systems can provide the basis for applying machine learning to human performance. The T&E and operational systems that have been instrumented to report performance can generate a large amount of data that can be analyzed to issue credentials, track assertions that indicate skill decay, and capture when managers revoke credentials due to behavior. The LRS Service, which captures all authoritative data from activity providers, is the point where other TLA components can view evidence. The competency manager leverages that evidence, aligns it to a competency framework, and generates trusted assertions in the form of xAPI. That trusted xAPI data is then stored in the Trusted LRS. The Trusted LRS provides portability of competency data since it is now in a standard format (xAPI) and allows TLAs to change out competency systems as necessary without losing their historic records.

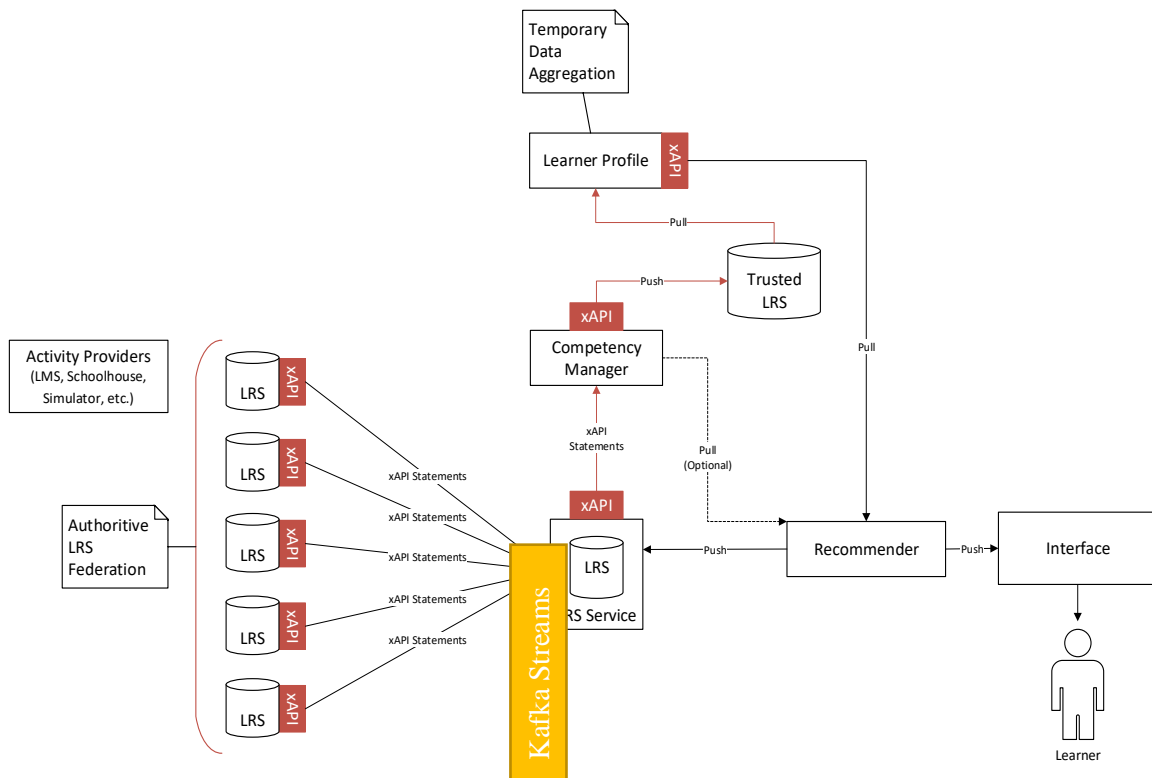


Figure 9. TLA Architecture with Two LRS Federations - Loosely based on the 2018 TLA reference implementation, this graphic shows the inclusion of a recommender that has access to both the learner profile and the transactional LRS data store.

Figure 9 presents a mature version of the future learning ecosystem. This is based on the 2018 TLA reference implementation. There is a high-likelihood that some systems (e.g., intelligent tutoring systems, recommenders, simulators) will need direct access to the transactional layer instead of only accessing the authoritative data stored in a learner profile. This instantiation can aggregate learner data from all types of systems in a way that allows a recommender to provide just-in-time feedback to an individual based on their actual performance.

The evolution towards this level of TLA adoption requires change across all the institutional barriers across the DoD. Changes will be required in the policies and processes we use to acquire systems such that they can be instrumented to publish key performance indicators that can be aligned to competencies. Lastly, the massive undertaking of creating frameworks, aligning evidence, and gaining access to that evidence is not trivial.

5. DISTRIBUTED ACYCLIC GRAPHS AS THE EXPRESSION OF DIGITAL COMPETENCIES

The Institute of Electrical and Electronics Engineering (IEEE) Learning Technology Standards committee (LTSC) has defined a Data Model for Reusable Competency Definitions (RCD) under their 1484.20.1-2007 standard. This is a critical data point for discussion of competency within the TLA standards-oriented ecosystem. The IEEE defines an RCD as “any aspect of competence, such as knowledge, skill, attitude, ability, or learning objective.”

Using this as a guide, any formal learning opportunities in use today would preserve the Enabling Learning Objectives/Terminal Learning Objectives (ELOs/TLO) structure in place by mapping those ELOs/TLOs to one or many RCDs within many frameworks. As shown in **Figure 10** below, the nodes within a competency framework can have many relationships that are bi-directional in nature. From this perspective, competency is not strictly hierarchal, and a single job may align with multiple competencies. Experience has shown that many frameworks are structured both in hierarchy and in time. Time represents two variables within CBL: the linear progression of how traditional education is scheduled and the rate that competency degrades in an individual.

Mathematically, the RCD is expected to behave as a Distributed Acyclic Graph (DAG). In graph theory, a DAG structure consists of nodes that are connected to each other with edges. Each node in the graph is analogous to a competency object and the edges define the relationship between them. Each node may have numerous edges connected to it and the relationships are directed in that they have a direction. $A \rightarrow B$ is not the same as $B \rightarrow A$. Acyclic infers that the relationships are non-circular and that when moving from node to node by following the edges, you will never encounter the same node a second time.

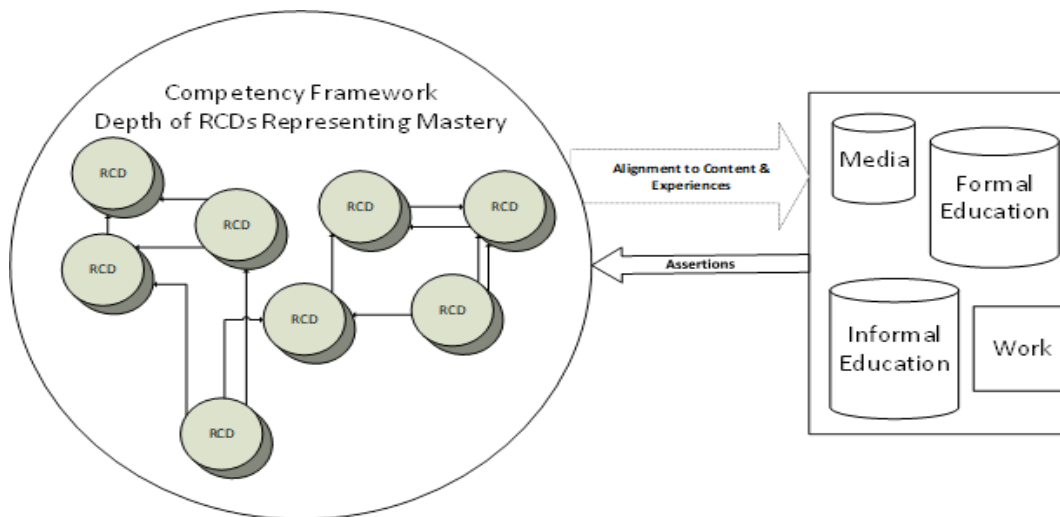


Figure 10. Relating a Framework to Learning - IEEE 1484.20.1 standard for Reusable Competency Definitions provides the foundation for a competency framework that can be used to align learning content, formal and informal training opportunities, and work experience.

Attaining mastery is the goal of individuals being managed within a competency framework. RCDs can be affected by a variety of assertions under a given set of standards and conditions. Two individuals may experience different working conditions for their given role, but the related framework must track mastery without any biasing. Most competency frameworks in industry and academia start with a single content object and extend to other learning activities to support its pursuit academically. Content objects usually include media, courseware, and scheduled on-the-job training.

This approach accelerates the obtainment of a credential but does not allow informal learning and work experiences to be included in the calculation. Skill decay mapping is also decoupled when the focus is on content since the updating of content is highly dependent on funding cycles in the DoD. Content is part of logistics⁹ and its updates are driven by two factors: schedule or workplace problems. Competency assertions offer the opportunity to drive updates to available formal and informal learning based on actual human performance.

The concept of utilizing performance data from operational systems to predict competency is relatively new. This is substantially different than traditional educational pipelines. In those pipelines, assertions are scaled to fulfilling a credential, which typically includes numerous competencies. Competencies are independent of time and may be completed piecemeal due to the experiences of individuals. The varying experiences of individuals will initially require a predetermined structure of their “weight” in terms of the overall framework. Weighting for a single competency should reflect its complexity in relation to supporting competencies and is highly dependent on the context of how a learner applies this competency to their job. The alignment of evidence to competencies is highly contextual as well and will require weighting to quantify the different assertions being made.

A person lacking competency in basic concepts will struggle with more complex tasks. Different learning activities infer different levels of competence at different times within the continuum of learning. Thus, the weighting becomes a multivariate equation that involves the contextual weighting between related competencies, the weighting and currency of evidence, and the weighting of assertions that increase or decrease over time based on the context of the evidence. This would also afford competencies with multiple weights that reflect their context in a job or task.

6. THE WAY AHEAD

A 2016 Institute for Defense Analysis (IDA) report,¹⁰ identified six key research areas related to competency in practice within an organization. The report’s conclusions are repeated below:

Credentialing. Credentialing is one accepted means of verifying personnel qualifications that correlate with successful employment. In addition, credentialing must address employers’ changing requirements and individual workers’ changing skill levels over time. There are numerous credentials, both digital and paper-based, that need to be aggregated and accounted for. This is more of an engineering challenge than a research challenge.

Automation. The development and use of competency systems is resource intensive. More efficiency in implementing a competency-based system of personnel management is essential to facilitate widespread use. Automation is needed to support the generation of metadata, calculate the weighting of evidence, measure its context, calculate the roll-up relationships of different competency relationships based on the context of the job or role its being applied to, and generate competency frameworks from existing and disparate types of text-based documentation already available within the DoD.

⁹ NAVFAC Logistics guidance, see section 4.7.

<https://www.navy.mil/content/dam/navfac/Expeditionary/PDFs/NAVFACINST4081-1A-Encl1.pdf>

¹⁰ IDA, Review and Assessment of Personnel Competencies and Job Description Models and Methods, Belanich J et al, 2016 IDA Document D-5803

Taxonomy. Diverse structures and categorization taxonomies are used across organizations and occupational databases to describe competencies. This leads to difficulties in comparing people or roles. Additional research is needed to understand how controlled vocabularies might be used to describe different attributes of a competency.

Granularity. Inconsistency is common in the level of detail used to describe a specific position, role, or broader occupation within competency systems. Such variations complicate decisions about which competencies to use. Further, different learning activities can generate different amounts of meaningful data..

Validity. The relevance of competencies to roles and performance is not well substantiated. Content validity is the most common form of assessment but is less robust than assessment that depends on quantitative performance evidence.

Tailoring. The process of adapting general competency structures and databases to suit organizational missions and functions can take extensive effort and present many difficulties. Organizations can study what others have done or extract from generic databases of competencies to leverage existing resources. However, even such initial steps are resource intensive.

In the two years since this report was delivered to the ADL Initiative much of its content is still true. There are numerous competency systems in existence, but many barriers to connecting them. The work across DoD and civilian sectors to afford interoperability among these data silos is critical. A competency system is dependent on the validity of the frameworks, data flows, and evidence in the surrounding environment. The system should service, align, and preserve all necessary frameworks it services, rather than translating them into a specific language and discarding their previous data. This facilitates traceability over time and across frameworks thus enabling records portability. This data also needs to be immutable, validated, preserved, and ultimately shared with other learning systems that have a need for it. From an organizational perspective, additional research needs to be performed around the intersection of individual and team competencies.

CBL will also benefit from organizational vocabularies and classifications of competencies that can be attached as metadata to each competency object. This allows for a controlled vocabulary and descriptors that can be aligned across organizations. Metadata vocabularies might include descriptors that inform whether a competency includes psycho-motor skills, fine motor skills, cognitive skills, skill decay, or relevant environmental factors that affect or inform the description of a competency. This information is already collected in a typical Job Duty Task Analysis (JDTA) but is often discarded as instructional content is developed.

6.1 Next Steps

In FY2019, the ADL Initiative will pursue multiple activities related to CBL and maturing the overall TLA.

- 1.) The ADL Initiative has partnered with Air Education and Training Command (AETC) and USALearning to conduct a research effort (Air Force Learning Services Ecosystem (AFLSE)/TLA Baseline project). This project supports the inclusion of CBL and other TLA technologies into the AFLSE. A competency framework is being created for an Air Force Specialty Code (AFSC), TLA components will be integrated into AFLSE systems, and evidence will be collected from authoritative sources over a 6-month period.

- 2.) The ADL Initiative has prioritized the FY19 topic areas for the Broad Agency Announcement (BAA) to include a focus on defining the technical underpinnings of competencies, establishing a robust metadata strategy, and understanding the interplay between learner profile data, authoritative sources, and services.
- 3.) The ADL Initiative staff is continuing work on the 2019 TLA reference implementation and its migration to a data streaming architecture that continues research into federated LRSs and associated business rules, the implementation of a competency DAG, and the establishment of a modern learner profile.
- 4.) The Competency and Skills System (CaSS) is being hardened and stabilized for use in the AFLSE/TLA baseline project and potential transition to the USALearning/ADL Initiative learning warehouse. Authoring tools are being matured to better evaluate the associated level of effort for defining competencies, creating frameworks, and aligning evidence repositories.
- 5.) The ADL Initiative and USALearning are working through the Combatant Commanders Exercise Engagement and Training Transformation (CE2T2) program to take an enterprise look at the numerous DoD policies that need to change to support CLB within the DoD. This project is also collecting requirements across the services to enable a universal DoD learner profile and is exploring the concept of federated governance for authoring and maintaining competency frameworks across the numerous domains associated with the DoD.

6.2 Conclusions and Recommendations

CBL is the bridge to having a trusted and informed prediction of how service members can perform in their jobs. This data affords a new view of the warfighter in general and enables the DoD to better prepare its service members for any potential mission. It has the potential to align the different organizations across the DoD responsible for training and education, human resources/personnel, and the operational work environment. This alignment brings the potential for increased readiness and a long-term cost savings by optimizing the way our workforce does, trains, practices, and executes their jobs.

The migration to CBL provides strategic insights into overall human performance within a JCS. As individual competencies are evaluated, trends can be identified that expose faults in organizational workflow, system usability, and training & education. A big challenge with current systems is the disconnected pools of data stored across a learner's lifetime and across institutional boundaries. Those disconnected resources hold great potential but are currently barriers to realizing the insights that CBL can provide to workforce planning and talent management, mission effectiveness, and force readiness.

While the technology challenges associated with the migration to CBL are not trivial, the change to culture, policies, and budgets is huge. The underlying concepts of CBL are complex, difficult to describe, and require time to manifest a return on investment. Access and permissions need to be granted to pull evidentiary data from operational systems, and acquisition strategies need to be revised to align with an overall DoD data strategy that links performance outcomes with mission readiness to enable future planning and decision making.

With the different learning modernization programs going on across the DoD, we are afforded the opportunity to lay the groundwork for intelligent CBL systems, federated data governance, and data portability that is required to maintain our global security posture.

APPENDIX A - CONCEPTS AND DEFINITIONS

Assertions: This is a foundational concept to Competency Based Learning. Assertions are defined by Webster's Dictionary as a "statements of fact or belief." In terms of competencies, an assertion is the expression of a trusted fact or belief about a learner's proficiency in specific KSAOs associated with a competency. Assertions are typically proffered with corresponding evidence that infers a specific competency for a specific learner. Ideally, assertion evidence is immutable and persistent so that it cannot be repudiated. This evidence should be interoperable between learning ecosystems to allow different levels of sharing and mutual recognition of competency data across domains (e.g., military and civilian). This is exemplified in the relationship between the Defense Health Agency (DHA) and the Medical Departments within each service. This is also demonstrated in the relationships between the different elements of the Intelligence Community (IC) where teams frequently come together to collaborate.

Assessment: Assessment is the collection and evaluation of evidence that can be used to make assertions of competency. Many learning activities (e.g., reading a book) contribute to an individual's proficiency in a specific competency, but formal assessments are considered to have a higher confidence value in terms of evidence. In The T&E world, these may come from capstone training events or any number of formative and summative testing events. In the operational world, these come in the form of job reviews, after-action reviews, or other trusted, authoritative source. Thus, assessments are the driver for the evidence behind an individual's proficiency within a given competency and in a given context.

The context is critical for translating relevance from the different perspectives between a pure learning environment and an actual work environment. Context helps define proficiency levels for different models of skill acquisition (e.g., Dreyfus and Dreyfus¹¹). Adjudication of the assessment data within the overall competency framework is maintained by a competency management system and is captured in an assertion. In the current paradigm, institutions provide a credential (e.g., degree) that rolls up all assessments, but loses details of learners' experiences. Competency Management Systems could take in evidence from workplace efforts of individuals to maintain proficiency ratings according to accreditation standards.

Competency Based Learning (CBL): Competency Based Learning is focused on the application of skills and knowledge rather than on recollections of abstract concepts¹². Mastery is demonstrated through performance where learners apply the required KSAOs they need to do their job. The current model of education within the DoD places trust in the formal training each service member receives with little data collected about learning that occurs on the job. Competencies must be defined for all the different jobs and roles performed. These must be tied into a framework that accommodates technical skills, as well as professional, behavioral, functional, or even organizational skills. Key performance indicators for each competency should be identified and tied to mission outcomes and the systems/components used to achieve those outcomes. For example, aviation maintenance records often identify what tasks are being performed and by who. Using this information, a great deal of evidence is presented on the aviation mechanic's level of technical competencies by providing a ledger of the tasks they've performed.

¹¹ Dreyfus, Stuart E.; Dreyfus, Hubert L. (February 1980). *"A Five-Stage Model of the Mental Activities Involved in Directed Skill Acquisition"*

¹² Gervais, J. (2016). "The operational definition of competency-based education". *The Journal of Competency-Based Education*. 1: 98–106. <https://onlinelibrary.wiley.com/doi/full/10.1002/cbe2.1011>

Competencies are defined as networks of KSAOs that collectively define a set of related performance elements, along with any collected evidence that the learner has achieved mastery of these elements at some graduated level of performance (journeyman, master, etc.). A competency framework embodies this network and establishes the relationships between those elements. In traditional education, competencies are pursued by each learner according to a prescribed curriculum. This is both culturally driven and necessary from a practical, resource-management perspective. As seen in planning for its Ready Relevant Learning (RRL) program¹³, the US Navy is migrating a Sailor's initial training phases into a shortened format, then developing new instructional-design techniques to shift the remaining learning requirements to on-the-job training with performance support aides.

Competency: The DoD defines a competency as “an observable measurable pattern of knowledge, abilities, skills, and other characteristics that individuals need to successfully perform their work.”¹⁴ This conceptual definition does not specify the supporting characteristics that makes competencies actionable across a learning ecosystem, like an implementation of TLA. To that end, the ADL Initiative proposes an expansion on the previous definition: competencies are trusted, discrete, and encapsulated representations of KSAOs and other characteristics at the individual level necessary for performing a role within a specific context.

Competencies can be assessed and are severable under a specific context. Severability varies depending on how the KSAO is trusted and demonstrated within a network of competencies. Competencies must be functional on a global scale to evolve with learners over time. For example, soft-skills, like time-management, are critical during individuals' development and subsequent careers, but rarely are a component of their formal records. A model of how competencies relate as a network is a requirement for maximizing the return of a competency service within a TLA implementation.

Competency Object: An umbrella term used to describe any abstract statement of learning or performance expectations, and information related to the statement. Statements can be learning outcomes, competencies per se, learning objectives, professional roles, topics, classifications/collections, etc. A competency object might include the following:

- A unique identifier, competency name, and detailed information
- Descriptions of required activities and behaviors (pre-requisites, physical requirements, reading levels, ethics, etc.)
- Associated Knowledge, Skills, Attitudes, and Other facets (KSAOs)
- Enabling Learning Objectives and Terminal Learning Objectives (ELOs/TLOs)
- Tasks, conditions, and standards
- Assessments, certifications, qualifications

Competency Framework: A competency framework is a collection of competencies that provide clarification about successful performance in different roles at different levels throughout the organization. Competency frameworks are a network of KSAOs (or other characteristics) that can have many non-exclusive relationships. These frameworks can be associated with other constructs outside of a required learning outcome. A competency framework organizes the KSAOs needed to perform successfully in a work setting, such as a role, occupation, or industry, or within a pure learning setting such as an academic

¹³ "Ready Relevant Learning (RRL) Official Website." U.S. Navy Hosting. Accessed May 14, 2019. <https://www.public.navy.mil/usff/rrl/Pages/default.aspx>.

¹⁴ DoD Competency Definition, DoDI 1400.25, June 2017

http://www.esd.whs.mil/Portals/54/Documents/DD/issuances/140025/140025_vol250.pdf

or vocational-training institution. The competency framework can be used as a resource for developing curriculum and selecting training materials, identifying licensure and certification requirements, writing role descriptions, recruiting and hiring workers, and evaluating employee performance.

The creation of competency frameworks requires extensive planning and investment. There is no universally consistent way for creating a competency framework. Many existing frameworks are represented by text that is scanned as Portable Document Format (pdf) files. They tend to not be easily searched, are not syntactically understandable to most computers, and do not have any capacity for automated configuration management as the frameworks evolve over time. A complete framework should include relationships to potential or allowable evidence (in the form of experiences or assessments from the work environment) that correlate to a demonstration of achievement for each competency by providing trusted evidence of mastery.

Competency Management System: A competency management system provides the foundation to strategic talent-management practices such as workforce planning, acquiring top talent, and developing employees to optimize their strengths. The ability to preserve granular data on KSAOs and maintain traceability between captured evidence and the state of an individual offers significant improvement over the current credential-oriented practices in talent management. Effective and automated competency management can create a real-time and predictive inventory of the capability of any workforce. Competency management is expected to provide these key capabilities:

- **Enriched understanding of expected behaviors and performance.** The quickest path to improving performance starts by knowing the target performance.
- **Improved talent management.** The mastery estimates about competence inform leadership about current and future capability. Data and analytics about employees' skills and knowledge are used by the competency management system as evidence to predict or assert confidence about a specific competency object.
- **Optimized talent development.** Enables the process of establishing training goals and plans that link to individual goal attainment, career planning, and succession planning. It also facilitates a personalized learning plan by aligning content with competencies specific to an individual's role within the organization.
- **Enhanced talent pipeline.** Competency management enables on-demand information about an individual's competency mastery and readiness to move into next-level or other critical roles. An individual's Career Trajectory is derived from their prior experience, education, and expertise and is influenced by numerous external and internal components.
- **Improved operational efficiency.** Competency management facilitates business-driven learning and development, eliminates non-value-added training, highlights strengths to be further developed, flags critical skill gaps for mitigation, and generates higher levels of employee and leader satisfaction with their overall experience with the organization.
- **Integrated broker.** There are numerous approaches to building competency frameworks. Competencies are encapsulated differently across industries, geographic regions, training domains, and even across our military services.

A Competency Management System preserves all KSAO data within a framework and aligns competencies with organizational goals, drives experience-building opportunities for individuals within the organization, and acts as a linkage between competencies and other talent-development processes. By preserving data throughout a learner’s career, this system can act as a brokerage service between a layer of trusted data that encapsulates the relationship between human performance and mission outcomes. *Figure 11* depicts the roll-up of KSAO data.

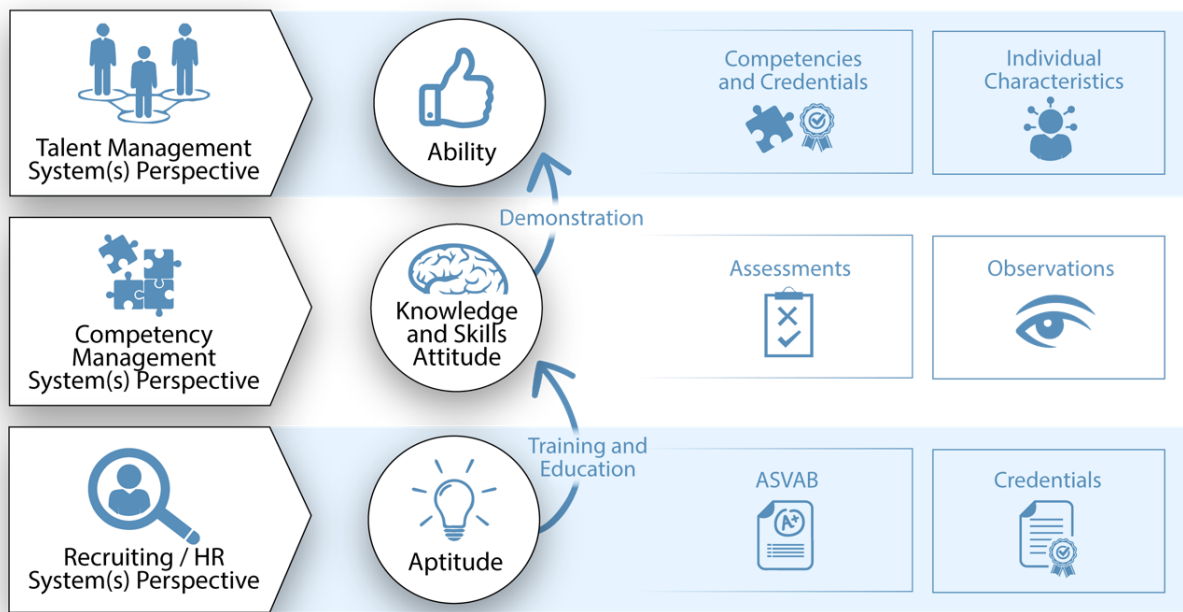


Figure 11. KSAO Roll-Up Competency - The evidence used to infer competency is derived from authoritative sources aligned with the KSAOs in any number of competency frameworks and preserved for further analysis and/or proof.

Competency vs. Credential: A network of competencies typically has varying mastery levels as part of its credentialing model. Previous levels contribute to the next level of mastery, and competency elements within the various levels may atrophy over time from disuse. Competencies are valued by the trust associated with them. Legacy credentialing models are dependent on the social value of groups of people trusting each other. The future of digital competencies derives trust from immutable data associated with discrete evidence that cannot be repudiated. These data can build from legacy constructs like certificates and degrees but preserving the raw elements of individual experiences for persistent consideration changes the possibilities for future education and training.

Credentials: A trusted exchange format that encapsulates a single competency or a set of competencies into an artifact from an accrediting organization. A credential is issued by an entity with authoritative power and provides proof of an individual’s qualification or competence in a subject. These artifacts range widely from a college degree to a professional certificate to a badge or a micro-credential. Possessing a credential not only helps one to prove competency and capability within a field, it also serves as verification that the individual is properly trained and equipped to carry out their duties within their specific vocations or disciplines.

In the current paradigm, credentials don't typically include data about the curricula or experience associated with the award of the credential. This is seen in degrees, where many years of abstract study and practical demonstration are distilled into a degree, associated with a transcript, and tied to a grade point average. For example, the domain of electrical engineering, governed by Accreditation Board for Engineering and Technology (ABET), Inc.,¹⁵ has an extensive requirement list for what an institution must do to have its bachelor's degree program accredited. At the point of conferring a degree, the student becomes a professional, and most of the performance data collected in obtaining the degree is lost. The degree, transcript, and GPA are trusted, but they do not provide much detail on the performance capabilities of the graduates. In theory, credentials can be issued at any level of granularity in relation to a competency and may "roll up" in many cases. Examples include assignments "rolling up" to transcript recorded grades, stacking professional certifications, or apprenticeships. Types of credentials include:

- **Badges:** Represent a way of acknowledging achievements or skill acquisition in a granular fashion. A badge is designed to motivate behavior, recognize achievement, and establish credibility. Badges capture knowledge, skills, and accomplishments that help transfer learning across different communities. Digital badges have emerged to document knowledge about a subject, professional development, leadership, or other accomplishments. The Open Badge¹⁶ initiative and other standards are built on the concept of capturing accomplishments, relating them to a graphical depiction, and then providing a validation process for assigning them. They do not necessarily need to represent attainment of a unique competency but have value in terms of social learning and motivation.
- **Certification:** A formal, but typically voluntary process that recognizes and validates an individual's qualifications in a certain subject. Certification is earned by individuals to assure they are qualified to perform a role or task through the acknowledgement of developmental achievement. Typically, a non-governmental entity grants a time-limited recognition to an individual after verifying that they have met a pre-determined criterion. Certificates verify that a professional has achieved a specific level of competence in a specific subject area and assures employers that the individual can handle the challenges associated with the role. Certifications are typically earned from a professional society or a commercial entity, like Microsoft or Cisco, and must be renewed periodically, generally through continuing education units and/or a reassessment of qualifications/capabilities. Examples include a Certified Project Manager from the Project Management Institute¹⁷, or a Microsoft Certified Solutions Expert (MCSE)¹⁸. Unlike licensure, individuals do not typically need to be certified to engage in given occupations. Sometimes, however, certifications become so important to certification attainment that they are quasi-mandatory.
- **Licensure:** A mandatory process by which a governmental agency grants time-limited permission to an individual to engage in a given occupation after verifying that he or she has met pre-

¹⁵ABET Engineering program requirements <http://www.abet.org/accreditation/accreditation-criteria/criteria-for-accrediting-engineering-programs-2017-2018/>

¹⁶ <https://www.imsglobal.org/sites/default/files/Badges/OBv2p0Final/index.html#intro-example>

¹⁷ www.pmi.org

¹⁸ <https://www.microsoft.com/en-us/learning/mcse-certification.aspx>

determined and standardized criteria. Examples include registered nurses¹⁹, a real estate agent²⁰, or professional engineers²¹. The goal of licensure is to ensure that licensees possess enough levels of competency to ensure that public health, safety, and welfare are reasonably well-protected.

- **Micro-Learning and Micro-Credentials:** Like badges, micro-credentials are performance-based assessments that allow learners to showcase their growing skills. *Micro-credential* is a term used to reference a subset of competencies that is significant enough to report (such as clearance to perform a medical procedure with a new device) that can be unique or build towards a more substantial credential. Micro-credentials are typically on-demand, shareable, and personalized. In some professional communities, individuals collect micro-credentials to document continuing education units that apply towards re-certification. To put micro-credentials in a broader context, learners typically have a choice in what credentials they want to pursue and can create their own developmental plans.

Credential Management System: A credential management system captures performance of individuals and publishes a certificate, degree, or qualification that is trusted in an organization. In the civilian domain, independent accrediting bodies play a critical role. In the military, independent accrediting bodies affect some domains but are not required across all areas. Credentials as the key measurement artifact tend to generalize people into designations that obfuscate granular metrics on their performance. This section describes how measurements become obscured in credentialing systems, and establishes granularity and traceability related to individual knowledge and skill as key concerns addressed by CBL.

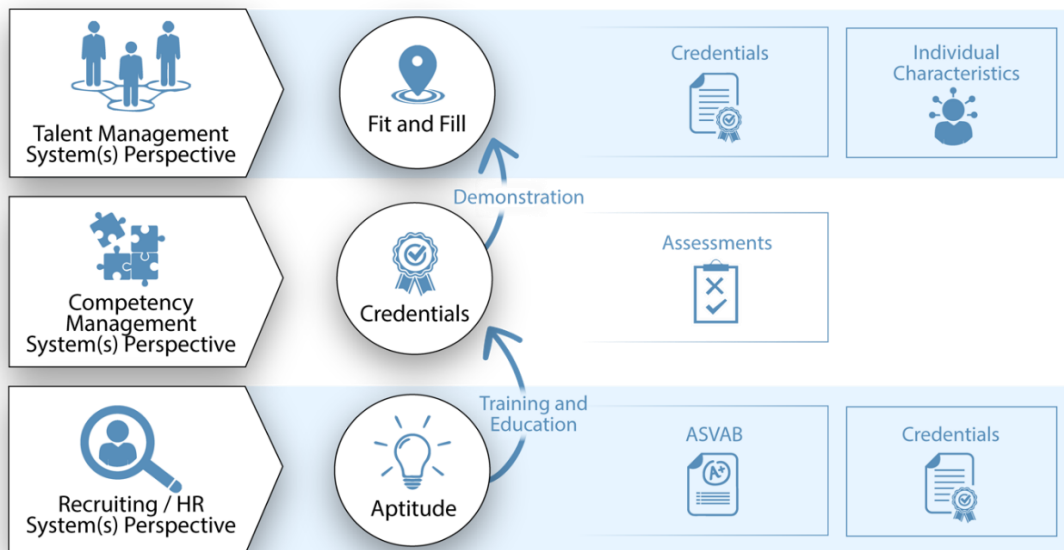


Figure 12. Credential Roll-Up - The services all have varying methods to prove proficiency upon being assigned a role in an operational environment. However, this is often based on assumptions about typically non-expiring credentials. By removing granular data, specific grading, and not providing a traceable data-set, leadership at the working level must build their own internal model of what subordinates can do based on limited data.

¹⁹ <https://www.ncsbn.org/nclex.htm>

²⁰ <https://www.kapre.com/resources/real-estate/requirements-to-get-a-real-estate-license/>

²¹ <https://ncees.org/engineering/pe/>

The Armed Services Vocational Aptitude Battery (ASVAB) combined with a High School Diploma or equivalent degree provides the baseline measurement for recruitment. After recruitment these few measurements represent the total measure of an individual entering the accession training. Compared to the individual's previous data set captured in high school, college, work environments, and other sources, the granularity of records has gone to a scale that obfuscates what the individual is capable of beyond anecdotal discussion. Specifically, demonstration of knowledge or skill upon entering the military requires self-identification on the individual and proving their ability in the workplace. Traceability is also sacrificed. An example is that aptitude to perform complex math problems identified by the ASVAB does not identify what formal mathematics education a service member obtained prior to enlistment. Many military schoolhouses pursue additional tutoring services for service members who join with difficulty reading or writing. If those records were preserved, overall learning could be tracked, and the DoD could better model how to educate moving forward at the individual level.

Upon completion of training, records of individual performance are captured within a credential. Individual performance, areas of strength or weakness, and soft-skill application are all lost, even though staff at training commands take note of these factors either formally or informally. As a service member enters the career phase, work experiences, as well as training and education experiences foster knowledge and skills to enable capture of credentials. Post accession service members are represented by their credentials, rank, and current medical condition at the talent management level. As shown in *Figure 12*, "Fit and Fill" is a common euphemism in the DoD for finding the right combination of rank and Navy Enlisted Classification/Military Occupational Specialty (NEC/MOS) credentials then placing them in a role.

Learner Profile: Learner profiles have the potential to empower personalized learning through the accumulation of better data that can inform learning in new and meaningful ways. A learner profile typically includes a broad range of data, including demographic data, data about student interests, learning preferences, inter- and intra-personal skills, existing competencies, and additional competencies that still need to be developed (in the personal, social-emotional, academic and career arenas). It might also include information on credentials or other student-learning strengths, needs, and types of support that have been successful in the past.

A learner profile might contain explicit goals about desired learner outcomes. When coupled with behaviors and experiences of other students, however, inferred data may inform valuable feedback sessions addressing fragile or missing skills, enable decisions about student placement, or highlight specific interventions needed to support success. Some elements of learner profiles afford learners a great deal of control. Just as learner profiles evolve over time to support personalization at the learner level, it is anticipated the learner has access to obtain, share, and interact with these artifacts, as well as controlling access to them by others, including other people, organizations, applications, and even other TLA components.

Safeguarding learner data to preserve privacy is an important legal and ethical consideration. This is especially true in the future learning ecosystem, where data-rich learner profiles and student achievement data are collected, stored and shared. The evolution from learner profile to student-owned pathways is key.

In education, a *transcript* is a copy of a student's permanent academic record, typically including all courses taken, all grades received, all honors received, and all degrees conferred to a student. A learner profile needs to consider this formal information while also being dynamic enough to document other achievements as individual learners are constantly changing and will become competent in new areas over time. This information about learners should be used – with learners' full cooperation – to determine their unique paths to achieving proficiency in all required and desired competencies throughout life.

Experience Application Program Interface (xAPI): xAPI²² is a specification currently going through the Institute of Electrical and Electronics Engineers (IEEE) - Learning Technology Standards Committee (LTSC) standards-development process (<https://www.tagxapi.org/>). It facilitates the collection of data about the wide range of experiences a person has (both online and offline). xAPI captures data in a consistent format about a person's or group's activities from many technologies. Different systems can securely communicate by capturing and sharing a stream of activities using xAPI simple vocabulary. xAPI specifies a structure to describe learning experiences and defines how these descriptions can be exchanged electronically. The main components of xAPI are the data structure called *statements* and the data storage/retrieval capability called the LRS. The xAPI specification has stringent requirements on the structure of this data and the capabilities of the LRS. Statements employ an *actor*, a *verb*, and an *object* to describe any experience. Each statement also includes timestamps and unique and traceable identifiers.

xAPI Profile: The “Companion Specification for xAPI Vocabularies”²³ released in March 2016, describes the general approach needed to strengthen the semantic interoperability of xAPI. The “xAPI Profiles Specification”²⁴ refines and extends the vocabulary specification to offer a common way to express controlled vocabularies, provide instructions on the formation of xAPI statements, and describe patterns of xAPI usage that provide additional context to a domain, device, or system. The xAPI Profiles Specification also adds tools to support authoring, management, discovery and/or adoption, including additional data elements and properties needed to support numerous use cases. A Benefit of xAPI Profiles is that they can standardize xAPI implementations across the “Internet of Learning Things (IoLT).”

²²xAPI Specification <https://github.com/adlnet/xAPI-Spec>)

²³ <https://adl.gitbooks.io/companion-specification-for-xapi-vocabularies/content/>

²⁴ <https://github.com/adlnet/xapi-profiles>

APPENDIX B – TECHNICAL STANDARDS AND SPECIFICATIONS

Achievement Standards Network™ (ASN™): ASN™ provides access to machine-readable representations of learning objectives and curriculum standards. It provides a Resource Description Framework (RDF)-based framework based on the Dublin Core Metadata Initiative's (DCMI) syntax-independent abstract information model (DCAM). The ASN™ framework is made up of *Standards Documents* and *Statements*. The Standards Document represents the overall competency framework, while Statements represent the individual achievements within the overall framework that can be asserted. A set of core properties define the relationships between the two in terms of an Entity-Relationship model. Structural relationships replicate the relationships between different components of the Standards Document, and semantic relationships define the relationships of meaning between statements (e.g., assertion of equivalence).

ASN™ is designed for interoperability and open access to learning objectives. It has seen wide adoption in the K-12 community. The ASN Description Framework (ASN-DF) provides the means to create ASN™ profiles through inclusion of additional properties/classes from other namespaces. ASN-DF provides a small vocabulary of classes and properties and a set of mechanisms for tailoring an ASN™ Profile based on the Dublin Core's conceptualization of application profiles and description templates.

Competencies and Academic Standards Exchange™ specification (CASE™): The IMS Global Competencies created the CASE™ specification to define how systems exchange and manage information about learning standards and/or competencies in a consistent and digitally-referenceable way. CASE™ connects standards and competencies to performance criteria and provides a way to transmit rubrics between various platforms. The CASE™ Service specification is the definition of how systems achieve the exchange of information about learning standards and/or competencies. Within CASE™, the underlying structure of both a competency and an academic standard are represented using the same data model. The data model is composed of three core constructs:

- The Root Definition Document – the top-level structure that collects the set of statements that define the individual competencies/academic standards. Within CASE, this structure is identified as the `CFDocument`.
- The Set of Composition Statements – the set of statements into which the top-level competency/academic standards have been decomposed. Within CASE, this structure is identified as the `CFItem`.
- The Rubric – the detailed definition of how it can be determined that mastery of the associated competency/standard has been achieved. This requires the definition of specific criteria used for each of the scores that can be awarded during an assessment. Within CASE, this structure is identified as the `CFRubric`.

The CASE™ specification defines internal relationships between statements like Parent/Child, Precedes, Is Related To, Exemplar, and Is Part Of. All competency frameworks published in CASE™ format can be linked together in a network of equivalent or aligned competencies. Having universal identifiers for each competency makes it possible for any tools or applications to share information between systems. The composition and logical structure of the data model for this hierarchical structure uses a linked list approach. Competencies must be related to programs, courses and modules, assessments, course materials, and learners' records of achievement. The CASE™ rubric is also suited for establishing the criteria and performance levels for earning credentials.

Occupational Information Network (O*Net): Valid data is essential to understanding the rapidly changing nature of work and how it affects the workforce. O*NET was developed under the sponsorship of the U.S. Department of Labor/Employment and Training Administration (USDOL/ETA) to facilitate and maintain a skilled workforce. Central to the project is the O*NET database, containing hundreds of standardized and occupation-specific descriptors on almost 1,000 occupations covering the entire U.S. economy.

Every occupation requires a different mix of knowledge, skills, and abilities and is performed using a variety of activities and tasks. As shown below in **Figure 13**, the O*NET database identifies, defines, describes, and classifies occupations through Experience Requirements (Training, Licensing), Work Requirements (Basic and Functional Skills), Occupation Requirements (Activities, Context), Worker Characteristics, Occupation Specific Information, and Occupational Characteristics. The O*NET Database includes a Military Transition search that connects occupations in the O*NET database to other classifications systems within the Military. This is accomplished through data from the Military Occupational Classification (MOC) system at the Defense Manpower Data Center (DMDC). This capability is also available via web services²⁵. Other resources include “Careers in the Military” and links to Army, Navy, Marine Corps, and Air Force COOL projects. Google²⁶ has recently released their own career recommender that leverages O*NET and military classification data.

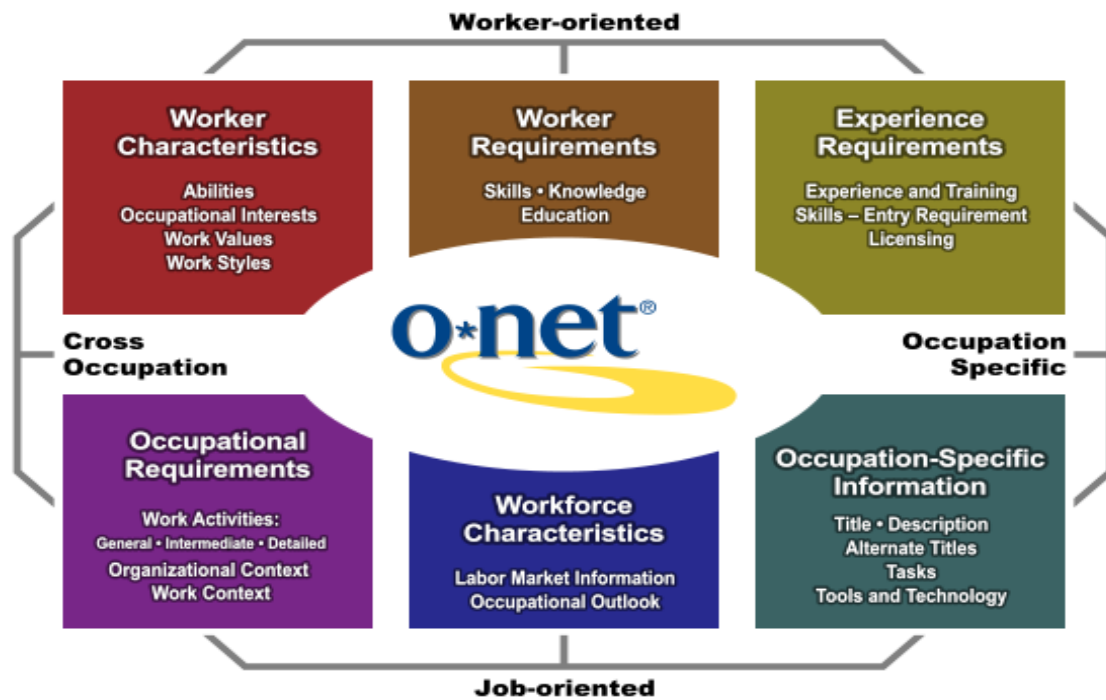


Figure 13. O*NET Content Model – This model provides the framework that identifies and organizes the distinguishing characteristics of an occupation. The model defines the key features of an occupation as a standardized, measurable set of variables called descriptors. This hierarchical model starts with six domains that expand to 277 descriptors.

²⁵ <https://www.onetcenter.org/crosswalks.html>

²⁶ Google Veteran Job Finder <https://qz.com/work/1371331/a-simple-tweak-to-google-search-now-helps-veterans-to-find-jobs/>

MedBiquitous Competency Framework (MEDBIQ CF): The use of outcome and competency frameworks is a growing part of healthcare education and maintenance of certification. The MedBiquitous Competency Framework, ANSI /MEDBIQ CF.10.1-2012, is a technical standard for representing competency frameworks in eXtensible Markup Language (XML). MedBiquitous is accredited by the American National Standards Institute (ANSI). Organizations that publish competency frameworks can do so in this standard format, making it easier to integrate competency frameworks into educational technologies like curriculum management systems.

The data model establishes relationships between competency objects that narrow or broaden the definition of overall competency. The MedBiquitous Competency Object specification provides a consistent format and data structure for defining a competency object, an abstract statement of learning or performance expectations, and information related to the statement. Statements can be learning outcomes, competencies, learning objectives, professional roles, topics, classifications/collections, etc. The Competency Object may include additional data to expand on or support the statement. This specification is meant to be used in concert with complementary specifications, including the MedBiquitous Competency Framework specification.

Reusable Competency Definition (RCD): The IEEE Standard for Learning Technology—Data Model for Reusable Competency Definitions (RCD) WG 20 will revise the 2008 Reusable Competency Definition (RCD) (1484.20.1) standard. The current standard defines a data model for describing, referencing, and sharing competency definitions, primarily in the context of online and distributed learning. The standard provides a way to represent formally the key characteristics of a competency, independent of its use in any specific context. It enables interoperability among learning systems that deal with competency information by providing a means for them to refer to common definitions with common meanings. The competencies WG 20 intends to take the Credential Ecosystem Mapping Project’s mapping of competencies metadata and update RCD to represent the most common elements that are found in multiple standards addressing competencies and competency frameworks. This effort started in September 2018 and will be monitored for progress.

Credential Transparency Description Language (CTDL)²⁷: CTDL is a vocabulary comprised of terms that are useful in making assertions about a credential and its relationships to other entities. CTDL defines terms for *Properties, Classes, Concept Schemes, and/or Data Types*. Like activity streams, the CTDL dictionary is comprised of nouns (classes) and verbs (properties) that allow us to make simple statements that enable a rich description of credential-related resources. This includes credentialing organizations and specific subclasses of credentials, such as *Degrees, Certificates, and Digital Badges*.

CTDL is modeled as a directed graph using the W3C’s Resource Description Framework (RDF) for describing data on the web. Like an activity stream, the “triple” is the

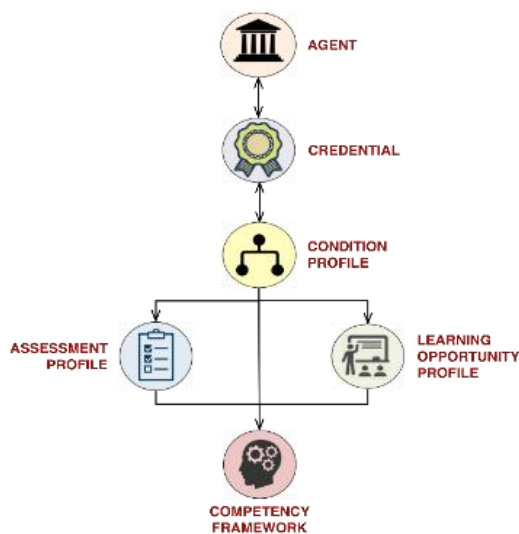


Figure 14. CDTL Class Structure

²⁷ <http://credreg.net/ctdl/handbook>

basic grammatical construct in making CTDL assertions about *things* and is comprised of three simple components: a subject, a predicate and an object. The comprehensiveness and scope of this specification makes it ideal for defining TLA Credentials. The CTDL is comprised of a small set of primary classes identifying major entities in the credentialing ecosystem.

As shown in **Figure 14**, CTDL provides clear guidance about the structure and terms used to describe attributes and assert relationships between all classes for each credential. Two super classes called *Agent* and *Credential* define families or sets of subclasses used throughout the CTDL. The primary classes also include the `ConditionProfile` used to define sets of constraints on the credential described by an *Assessment Profile*, *Learning Opportunity Profile*, or *Competency Framework*. These are used to express learning goals and outcomes in terms of knowledge, skills, and abilities across a diverse set of profiles.

Credential Registry: The Credential Registry²⁸ is both a repository of information regarding credentials and a set of services that make it easier to use that information. Together with CTDL, it provides for the capturing, connecting, archiving, and sharing of information about credentials (including degrees, certificates, certifications, licenses, apprenticeships, badges, micro-credentials, and more). It also registers credentialing organizations that issue these credentials to individual credential holders, including universities, colleges, schools, industry and professional associations, certification organizations, military, and more.

Credential Registry also allows users to see what various credentials represent in terms of competencies, transfer value, assessment rigor, third-party approval status, and much more. The Credential Registry works with CTDL to allow the storage of credentials that have been expressed using that specification. The Credential Engine project's developers are using the Dublin Core Application Profiles process to create systems that communicate virtually all aspects of credentials. The Technical Advisory Committee (TAC) promotes collaboration across, and harmonization of, standardization initiatives that are developing data models, vocabularies, and schemas for credentials and competency frameworks, as well as related competency information such as criticality ratings and assessment data typically captured with a wide variety of systems. The Credential Registry uses technology and CTDL to capture, link, update, and share up-to-date information about credentials so it can be organized and centralized within the Registry, and then made searchable by customized applications, and linkable from anywhere on the open Web.

The Credential Registry serves as a complement to the CTDL specification and meets required TLA registry capabilities for defining credentials. It is important to note that this is only a registry and, as such, only stores the description of a credential in the abstract sense. From this perspective, the registry can be used to house credentials created with other specifications (e.g., CASETM). The Credential Registry is not a store of personal information or of personally-obtained credentials. That information will be stored in the TLA Learner Profile.

IMS Global Open Badges: Open Badges²⁹ are information-rich visual representations of verifiable achievements earned by recipients. Open Badges is a technical specification and set of associated open-source software designed to enable the creation of verifiable credentials across a broad spectrum of learning experiences. The Open Badges standard describes a method for packaging information about

²⁸ <https://www.credentialengine.org/credentialregistry>

²⁹ <https://www.imsglobal.org/activity/digital-credentials-and-badges>

accomplishments, embedding it into portable image files as digital badges, and establishing resources for its validation and verification. Open Badges contain detailed metadata about achievements, such as who earned a badge, who issued it, and what it means. The Open Badges 2.0 specification expands on this capability to include versioning, endorsements, and full use of JavaScript Object Notation Linked Data (JSON-LD)³⁰.

The Open Badges Vocabulary defines several data classes used to express achievements that are understandable within software and services that implement Open Badges. There are three core data classes: *Assertions*, *Badge Classes*, and *Profiles*. Each data class is a collection of properties and values, and each defines which are mandatory and optional, as well as the restrictions on the values those properties may take. Each Badge Object may have additional properties in the form of an Open Badges Extension, a structure that follows a standard format so that any issuer, earner, or consumer can understand the information added to badges. Assertions are representations of an awarded badge, packaged for transmission as JSON objects with a set of mandatory and optional properties.

Open Badges are expressed as linked data so that badge resources can be connected and references as a permanent fixture in a TLA Learner Profile. The attributes defined by the Badge Class and Issuer Profile are clear and the rules surrounding the specification drive the interoperability. Finally, the URL usage of Badges and many of their properties (Evidence, Criteria, Image, Issuer, etc.) enable them to be easily accessed on the Web.

W3C Verifiable Claims: The mission of the Verifiable Claims Working Group (VCWG) is to make expressing and exchanging credentials that have been verified by a third party easier and more secure on the Web. Driver's licenses are used to claim that we can operate a motor vehicle, university degrees can be used to claim our education status, and government-issued passports enable holders to travel between countries. This specification provides a standard way to express these sorts of claims on the Web in a way that is cryptographically secure, privacy respecting, and automatically verifiable. A verifiable claim is a claim that is effectively tamper-proof, and whose authorship can be cryptographically verified. Multiple claims may be bundled together into a set of claims.

The basic components of a set of verifiable claims include a *Subject Identifier*, *Claims about the Subject*, *Claim Set Metadata*, and a *Digital Signature*. Both the Entity Profile Model and Entity Credential Model consist of a collection of name-value pairs that are referred to as properties in the data model. The link between the two is in the ID property. The Entity Profile Model defines a subject identifier in the id property, while the claims section of the Entity Credential Model uses the id property to refer to that subject identifier. Unlike the properties in the Entity Profile Model, the properties in the claim section of the Entity Credential Model are claims made by an entity about the subject defined in an entity profile.

Additional research is required to better evaluate its applicability to the TLA. However, the defined data model and structure of this specification implies that it could connect to the TLA both semantically and syntactically. The data associated with verifiable claims are largely susceptible to privacy violations when shared with other TLA components, so many of the Verifiable Claims – Use Cases should be examined to inform how Personal Identifying Information (PII) connected to credentials can be protected within the security boundaries of the TLA.

³⁰ JSON-LD <https://json-ld.org/>

Comprehensive Learner Record (CLR): IMS Global led the development of the CLR (<https://www.imsglobal.org/activity/comprehensive-learner-record>), formerly known as the Extended Transcript, it is designed to support traditional academic programs and co-curricular and competency-based education in order to capture and communicate a learner's achievements in verifiable digital form. The vision for the learner record is transformative in its potential, beyond providing relevant student competencies and skills. Closely following the developing registrar guidance of American Association of Collegiate Registrars and Admissions Officers (AACRAO), the vision for CLR is a secure, student-centered digital record for the 21st century.

The CLR standard is a new generation of secure, verifiable digital records for learners, containing all nature of learning experiences and achievements including courses, competencies, skills, co-curricular achievements, prior learning, internships and experiential learning. This variety of credentials targeted by this standard could make it viable as a TLA Credential standard. The CLR seems to be versioned according to the Extended Transcript standard. At the time of this report, the support of these efforts, and the emerging IMS Pathways specification are unknown.