Metadata in the Future Learning Ecosystem

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ABSTRACT

Big data in training and education is becoming increasingly important in realizing the full benefits of a future learning ecosystem. Metadata tags are commonly used to describe the context behind training and education data assets, and implementing data governance through metadata implementation has many strategic benefits for organizations. Proper use of metadata unlocks possibilities for automation, machine learning, and a broad range of data-driven capabilities for the training and education domain. These capabilities promise to enhance operational readiness by making full use of the bounteous data sets continuously produced by modern technology. Most of this data is disconnected and stored within proprietary data silos; however, the next generation of information architectures and commercial data standards will enable the exposure of these data assets for use by other enterprise systems.

These advancements are helping to standardize the data formats and communication protocols that applications use to adapt training based on learner performance, align training with the needs of the organization, and enable improved analytics and insights. Several general-purpose metadata standards currently exist, and many others are in development. These standards promote a common approach to describing data such as definitions of competency, descriptions of learning activities, and global attributes of learners. As the training and education community works to modernize the continuum of lifelong learning, new capabilities must be designed around these standards to automate the generation and collection of metadata.

This paper summarizes the ADL Initiative's efforts to create new metadata guidance for DoD stakeholders. This work builds upon existing standards while increasing the scope, precision, and applicability of metadata. The paper discusses the different governance considerations for managing the lifecycle of metadata and explains how these new metadata initiatives address the significant gaps in older standards. It also provides technical and strategic recommendations to facilitate adoption and transition.

ABOUT THE AUTHORS

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INTRODUCTION

Technology is changing the way we live and learn. The digital world around us creates a web of learning resources that are accessible in the workplace, from home, through social circles, and on a growing variety of media and devices. The exponential growth of data generated by these systems has the potential to enable better insights while reducing costs through continuous process improvement across all education and training activities. Enterprise analytics now allows for new ways to assess the effectiveness of training content and instructional strategies for different learners, and to understand organizational trends through access to large volumes of education data.

The key to managing lifelong learning data across the future Department of Defense (DoD) learning ecosystem is the interoperability afforded through the technical standards, specifications, and practices that underpin an integrated data strategy (Vogel-Walcutt, Schatz, et al., 2019). Technical specifications and standards are available to support this strategy by enabling different learning resources to communicate with each other using a common, agreed-upon "language." These standards establish consistent protocols that can be universally understood and adopted by any component within the DoD to exchange data about learners, activities, and experiences. These underpinnings tie together the wide range of learning resources an individual will encounter and enable the sharing of this information with other systems and platforms across institutional boundaries. Data-driven decisions are enabled through enterprise-level analyses of this learning data, supporting the continual refinement of manpower skillset definitions and the creation, selection, and maintenance of learning activities necessary to achieve proficiency.

Metadata refers to data that describes other data. It is structured information that describes and explains data in order to make it easier to locate, retrieve, use, and manage an information resource (National Information Standards Organization, 2020). It gives data the context and meaning needed to derive insights. On most webpages, metadata consists of tags that help other websites and applications understand what the page is about. In the context of distributed learning, metadata has historically been applied to the description of learning resources, such as instructional content or other curriculum-related assets. For these resources, metadata may include information such as author, file size, subject, title, and duration.

Within the broader context of training and education, there is a wide range of data types and formats that utilize different types of metadata. Metadata is included in photographs, video, textbooks, simulator systems, and the full spectrum of activities and content used to deliver training and education to our military personnel. Other types of metadata commonly used across the training and education community include descriptions of competencies, credentials, learner context, and other attributes. The aggregate of this data has the potential to become a critical component of the human capital supply chain within DoD.

Learning data at any level of granularity can be described with metadata, but the value of metadata goes beyond the basic use case of providing descriptive information. Metadata can also provide more strategic benefits, such as enabling automation of labor-intensive processes, enhancing analytics and insights into learning, and powering adaptive instructional systems that personalize learning experiences and optimize efficiencies across the organization to improve workplace performance. To take advantage of these more advanced capabilities, organizations must have a comprehensive *metadata strategy* that aligns with their goals.

Building a Metadata Strategy

Metadata unlocks the value of data, and therefore requires effective management to ensure proper creation, storage, integration, and control to support its use. A metadata strategy is a plan that articulates what an organization needs from its metadata and how it will be used. It provides a focus on how data assets are shared across an organization and enables a uniform approach for managing an organization's data ecosystem. An effective metadata strategy will address the current and future data needs of an enterprise and will define the different processes involved with making that data effective and efficient in supporting business activities.

Many types of metadata exist, including descriptive, structural, administrative, referential, and statistical metadata. In the complex world of education data, the more comprehensive the metadata is on a resource, the easier it is for other tools and services to find and utilize the data (National Forum on Education Statistics, 2009). Legacy learning metadata standards tend to focus on learning resources, like textbooks or online videos, used in an educational setting. This type of metadata (i.e., the who, what, when, where, why, and how) is fundamental to the most basic operation of a data system, but many organizations, both within and outside of education, are unable to answer such basic questions about the data they maintain. In recent years, the education enterprise has grown in complexity, resulting in the seemingly exponential growth of information collected, stored, managed, used, and reported.

A well-designed metadata strategy minimizes disruption to data management and use. It ensures that the descriptions, definitions, parameters, usage instructions, and history of each element are maintained in an accurate and up-to-date manner. Many factors are important to consider when developing a metadata strategy, such as:

- What are the organizational goals and business drivers? Commercial enterprises, educational institutions, and government entities (especially military forces) have different priorities for their training and education programs. These priorities drive the information needs and characteristics required to determine an optimal metadata strategy for each organization.

- What are the technical and logistical capabilities of the organization? Newer learning modalities, such as virtual reality, mobile learning content, and simulations, require a different approach from web-based courseware being delivered from a learning management system (LMS).

- What is the scope and scale of the information enterprise? Is the enterprise a small business with a few dozen learner records, or a component of the DoD with a few million? To optimize data quality, it is not enough to clean up the existing historical data. The enterprise must also consider who within the organization is responsible for creating, generating, and maintaining the data.

- What are the organizational policies and procedures for data governance? If a metadata strategy is created to reflect an education agency's long-range vision, goals, and information needs, support for system development, use, and maintenance must exist at the highest levels of the organization.

- How does an organization's metadata interrelate? The type of information architecture used in the organization will influence how data elements interact. These are encapsulated into a metamodel that maps and illustrates how data elements, metadata items, business rules, subsystems, data repositories, data flows, and information needs relate to one another.

In general terms, a *metamodel* is a formal description of how metadata supports the information needs of an organization. Like any data model, a metamodel helps illustrate relationships between metadata items and the data around which it is generated. These reflect the technical and operational parameters in which the metadata items exist, including layout, file structures, and other characteristics. The ADL Initiative is working with the Institute of Electrical and Electronics Engineers (IEEE) Learning Technology Standards Committee (LTSC) to create a series of interoperable metamodels that may be implemented in a systematic manner across the DoD to enable a new generation of connected tools and technologies that help improve efficiency and effectiveness across the DoD's training and education community.

METADATA STANDARDS

Metadata itself is not a new phenomenon. Even before digital learning resources were in wide use, libraries recorded metadata about the items in their physical collections. As digital media gradually rose to prominence, various communities of practice established *metadata standards* for their fields, such as library science and biomedical research. These standards improved discoverability of resources and interoperability between disparate digital systems. For example, many digital photographs contain metadata about the model of camera used to take the picture, photographic exposure information, and keywords that can be used by search engines. These photographic metadata standards are maintained by several organizations in concert so that a digital photograph's metadata can be read and interpreted the same way across various operating systems, camera models, and graphics editors.

These standards were a crucial first step toward long-term interoperability, allowing easier discovery of digital assets via search engines and enabling disparate systems to process and understand each other's data, a phenomenon known as *semantic interoperability*. Artificial intelligence (AI) is becoming more prevalent across the training and education domain, and modern technology is producing more data than ever before. However, AI is fundamentally dependent upon the quality of its input data—garbage in, garbage out. Therefore, to help AI-based systems produce useful results, semantic interoperability must be a priority of any metadata implementation. Standards help ensure that the DoD's training and education data can be read and interpreted by any AI solution across the DoD, instead of requiring custom integration into each different component.

In distributed learning, there are several general-purpose metadata standards that have been widely adopted by a mix of DoD stakeholders. Work by organizations such as the Dublin Core Metadata Initiative (DCMI), the IEEE LTSC, and the IMS Global Learning Consortium has resulted in standard data models that facilitate networked information discovery and retrieval throughout the distributed learning community. These data models have provided critical foundations for the growing infrastructure that supports distributed learning. However, over the past 20 years, education and training has migrated from a content-centric to a context-centric paradigm where distributed learning is only one tool in an organization's training toolbox.

Lifelong learning is a continuous process that includes learning in different contexts (O'Grady, 2013). The technology available is constantly changing and the next generation of learning activities cannot be defined within the context of a single LMS. In today's world, an individual's lifelong learning continuum is distributed across numerous technology platforms that use different instructional methodologies and learning activities. Learning can no longer be divided into a place and time to acquire knowledge (school) and a place and time to apply the acquired knowledge (the workplace). The future learning ecosystem will be defined by personalized and competency-based learning environments that rely on the availability and accessibility of learner data across organizational and institutional boundaries throughout an individual's life.

The multitude of ways that learning takes place highlights the issue of context in determining what will best inform the next generation of metadata schemas to support learning, education, and training (McGreal, 2004). Context can be understood as a critical component in any value chain that renders data and information into knowledge. To address these trends, many DoD components are undergoing their own modernization efforts, with direct support from the ADL Initiative. This is exemplified by the work being performed with the Office of the Undersecretary of Defense for Intelligence (OUSD(I)) on their Talent Development Toolkit (TDT) project (Gordon, 2019). Among other things, this project addresses the limitations faced by the intelligence community in exchanging learner-related data among 17 different organizations.

Through the Total Learning Architecture (TLA) project, the ADL Initiative is designing a framework of commercial standards, technical specifications, and business rules to enable plug-and-play interoperability across all learning technologies. The TLA data strategy provides a common set of metamodels across DoD's education and training community to ensure training and education data is used effectively. These commercial standards describe the data within the four pillars of the TLA data strategy:

- **IEEE P9274.1 xAPI 2.0** – Learning activity tracking uses the Experience Application Programming Interface (xAPI) and JavaScript Object Notation (JSON) standards to capture learning activity streams. The cmi5 specification and the TLA Master Object Model (MOM) are also in this data pillar since they contain an xAPI profile. xAPI 2.0 is targeted for approval in 2020.

- **IEEE P2881 Learning Metadata** – Descriptions of learning activities and their associated content are stored in the TLA's experience index and use a modified version of the Learning Resource Metadata Initiative (LRMI) standard.

- **IEEE 1484.20.1 Reusable Competency Definition** (RCD) – The competency framework, which includes the definition of a competency, the relationship to other competencies, and the alignment of evidence to help measure proficiency of the competency, are included in the RCD standard. This standard is expected to be approved in 2020.

- **IEEE 1484.2 ILR** or **IMS Global CLR** – Learner profile standards do not currently meet all TLA requirements. New standards are being developed based on input from numerous industry groups and associations. The learner profile will likely include credential sharing using Open Badges 3.0 and the Credential Transparency Description Language (CTDL).

Federating these data types between different DoD components and their associated networks will enable enterprise-level services by granting semantic interoperability, global discoverability, and security. It will provide an end-to-end system that is integrated, personalized, data-driven, and responsive to changes in the threat and technical environment. This approach decouples the various learning functions typically included as part of a traditional LMS into composable data and services that address learning experiences across the continuum of learning and connect at scale to data across the DoD. Another benefit of this approach is the ability to process the same metadata for different purposes. For instance, one learning tool may be able to calculate the gaps between a learner's selected goals and their current competency levels, while another component may determine the most efficient learning path to the goal.

TECHNICAL CONSIDERATIONS

By providing a set of executable policies, specifications, and commercial standards for each metamodel, the different learning systems, tools, and activities will be able to communicate with each other using a common language. These standards serve as building blocks for lifelong learning by establishing consistent protocols that can be universally understood and adopted by any new learning capability, enabling data exchange about learners, activities, and experiences. The following sections describe a conceptual model for how different metadata is used across the future learning ecosystem.

The Suite of xAPI Standards

xAPI (IEEE 9274.1) is a data specification, based on JSON, that enables the capture and sharing of fine-grained learner data (ADL Initiative, 2017). While not itself a metadata standard, xAPI plays a pivotal role in expanding the use of metadata in a future DoD learning ecosystem. 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 structures called *statements* and the LRS data store.

The xAPI specification has stringent requirements on the structure of these statements and the capabilities of the LRS. The xAPI data format describes an activity statement with using 11 attributes: Unique Identifier, Actor, Verb, Object, Result, Context, Timestamp, Stored, Authority, Protocol, and Attachment. The minimal descriptive information of an xAPI activity statement is the Actor, Verb, and Object triple. All other properties are optional and can be categorized into metadata and complementary data (Nouira, Cheniti-Belcadhi, and Braham, 2018). For example, to express statements related to assessment activities, each statement may be described using the Result property. The Result property can then be described with different metadata about the assessment result such as the score, success, duration, or completion status. This information is used later to support enhanced learner analytics and insights.

As shown in Figure 1, any learning activity can be instrumented to send xAPI statements to any number of other learning systems. Each activity has a unique identifier that may be encoded into the xAPI Object IDs so that any system accessing that data can retrieve the activity's associated Learning Activity Metadata file (IEEE P2881). When collecting data from these systems, organizations need to be able to shape their xAPI data, semantically standardize it, and identify unique patterns and contexts. The *xAPI Profile Specification* (IEEE 9274.2) offers a common way to document the vocabulary concepts, extensions, statement templates, and patterns that are required for xAPI to be implemented consistently across the spectrum of learning activities an individual will encounter.

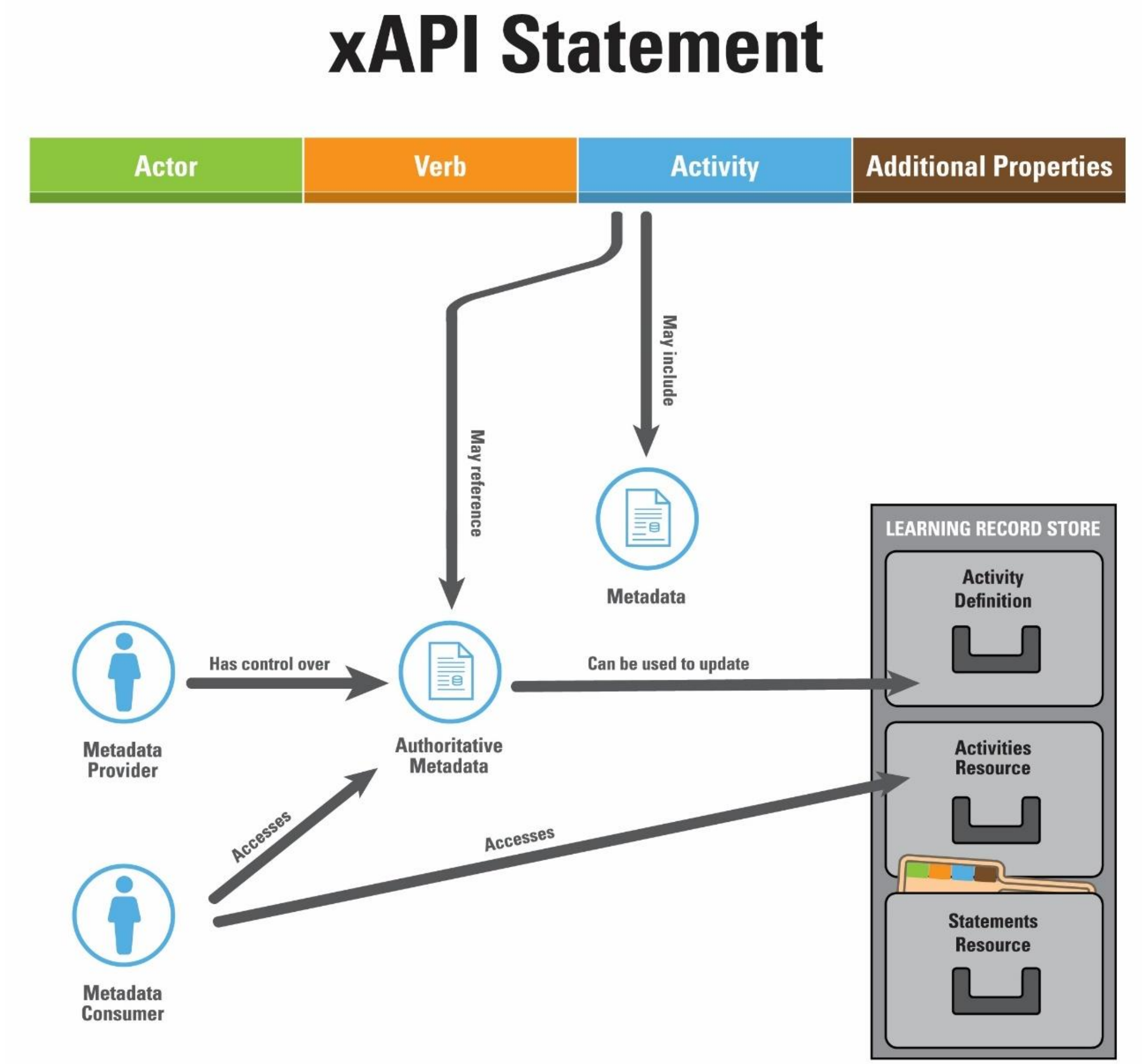

Figure 1. xAPI statements and metadata.

Part of the ADL Initiative's research has been to explore methods for preserving "learner-centricity" across a wide range of learning activities. The TLA MOM is an xAPI profile that abstracts performance adjudication from the learning activity by following the *learning event lifecycle*. Using verbs defined in the cmi5 specification (Aviation Industry Computer-Based Training Committee, 2016), learning activities report success or failure to a higher-level LRS, whereas lower-level performance data may be kept on a local LRS. This enables the evaluation of trust in the evidence used to update competencies and credentials. It also provides reference points in collected performance data to filter and organize enterprise analytics within the decision support system. Most importantly, it normalizes the events necessary to trigger microservices to take actions without an overall state manager. This forms the decoupling and data segmentation approach used for LRS federation.

Within the TLA MOM are embedded chains of evidence that ensure "learner-centricity" is preserved across a wide range of learning activities or other DoD learning systems. This establishes an auditable trail of demonstrated competency to back up each awarded credential. It also preserves the digital signatures of those trusted to review and confer credentials.

Standard for Learning Metadata

As part of ongoing TLA research, the ADL Initiative conducted analyses of the common educational metadata standards in current use, including LRMI, Schema.org, Dublin Core, and Learning Object Metadata (LOM). The ADL Initiative's TLA research relied heavily on the LRMI metadata framework (Dublin Core Metadata Initiative, 2014) and LOM. The initial goal of LRMI was to expand Schema.org with attributes that could be used specifically for learning resources. Schema.org was launched in 2011 by several of the world's leading search engines to create and promote schemas for online structured data. Most LRMI attributes are applied to either the "CreativeWork" object type or the "AlignmentObject" object type that describes an alignment between a learning resource and a node in an RCD Competency Framework. The IEEE 1484.12 standard *Learning Object Metadata* is an internationally recognized learning resource data model that was standardized by the IEEE in 2002 (IEEE, 2002). LOM has been widely adopted for distributed learning across the world because of its use in the Sharable Content Object Reference Model's (SCORM) content packaging specification. LOM contains many predefined fields for describing learning content. SCORM also permits the extension of LOM to allow organizations to specify additional metadata.

Through the TLA working group's subcommittee on metadata, ADL Initiative staff continued to evolve the metadata strategy based on the technical interchange with different DoD stakeholders. These discussions helped align the goals of the subcommittee with the DoD's programmatic requirements across different modernization efforts. These efforts have led to a Project Authorization Request (PAR) approved by IEEE as P2881, *Standard for Learning Metadata*. P2881 aims to build on the IEEE LOM standard while distinguishing between learning resource types to enhance semantic interoperability. It will also incorporate new fields from LRMI and other standards to enable more precise data collection. This new standard will retain LRMI's extensibility and LOM's taxonomic structure, but also distinguish between different types of learning resources, as different attributes apply to each learning resource type. For example, physical location may be an essential characteristic for a live field exercise activity, but it may not applicable to a textbook or online video used as part of that activity.

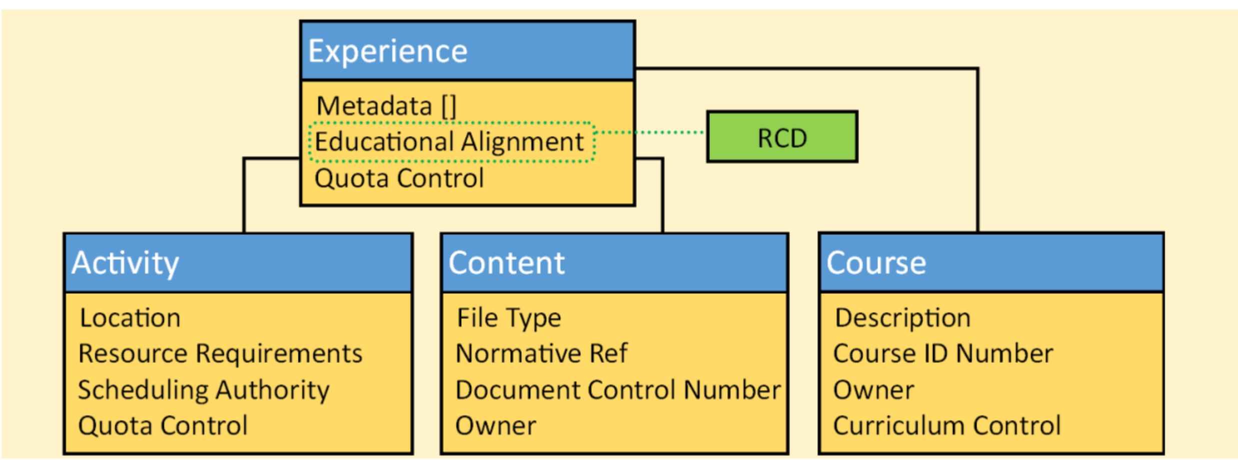

Figure 2. Relationship between Experience, Activity, Content, and Course.

As shown in Figure 2, the P2881 metamodel expands the types of learning activities a learner may encounter by acknowledging the relationship between instructional content and the various instructional activities where that content is presented to the learner. The term *activity* describes the context of the work, such as simulation, LMS, e-book, or classroom lecture. The term *content* describes the digital artifacts used in the activity, such as a scenario, sharable content object, checklist, or technical manual. Data elements are segmented for configuration management and search performance and exported in a modified LRMI format.

The IEEE P2881 working group will solicit feedback and recommendations from its stakeholders and other communities of interest to improve its metadata recommendations and implementation strategies. Additionally, it aims to accommodate new learning technologies as they become available. The metadata guidance that will be produced by this working group is not intended to replace or supersede legacy standards, but instead build upon the body of existing work in a manner that allows for easy transition by retaining many legacy standards' useful characteristics.

A large component of the 2019 research involved defining the lifecycle of metadata across human-readable and machine-readable formats. While human-readable metadata is typically created during the development of instructional activities, the next generation of learning tools will automate the process of creating machine-readable metadata that uses *paradata* about how each activity and its content is being used across the enterprise. The greatest need for curating learning resources using machine learning and artificial intelligence is access to usage data that is typically locked away in proprietary disconnected data silos. In one prominent institution, course metadata is locked away in multiple course catalogs while course surveys that are completed for every course are stored in a data warehouse and course statistics are located within the registration system. In the future, automated systems will pull this data into a single catalog that rolls up to a Defense-wide catalog network.

Reusable Competency Definitions (RCD)

Competency-based learning represents a transition from curricula focused on abstract knowledge and pursuit of certificates to curricula built around authoritative learner performance and proficiency indicators. Competencies describe specifically what people need to do to be effective in their roles, and they clearly establish how their roles relate to organizational goals and success. Each job has its own set of competency requirements. *Proficiency* is another critical concept that requires relevant, trusted data as evidence of mastery of specific skill requirements.

Competency management requires the generation of rich, traceable data about learning experiences, how they relate to skill proficiency, and the knowledge, skills, aptitudes, and other traits (KSAOs) that individuals need to do their jobs. A *competency framework* is a structure for defining the KSAOs required to do a job. Competency frameworks are widely used in business for defining and assessing competencies within organizations for successful job performance. As shown in **Figure 3**, the RCD standard uses linked data to define all aspects of a competency, including key performance indicators, formal assessments, and other measures of proficiency. The RCD standard provides a mathematical formalism for defining competencies and describing the relationships among competencies within a competency framework.

Competency models are almost entirely composed of metadata. Some RCD attributes, such as the “description” field, are designed to be human-readable. Others, such as “language,” must follow strict guidelines to ensure machine-readability. The use of linked data to enable semantic precision is designed around use of Schema.org’s capability to anchor linked data definitions and fully qualified namespaces. The RCD specification accounts for the possibility that the same competency may exist with different titles or descriptions in various systems by employing a globally unique identifier. Within the TLA data strategy, each RCD node includes a unique identifier that can be referenced and linked to other metamodels. For example, both LRMI and CTDL link to these identifiers to provide an alignment between learning activities, competencies, and awarded credentials. Key to establishing assertions of competency from an *activity stream* is the reconciliation between the “Actor” in a statement (stored in an LRS) and a persistent learner profile.

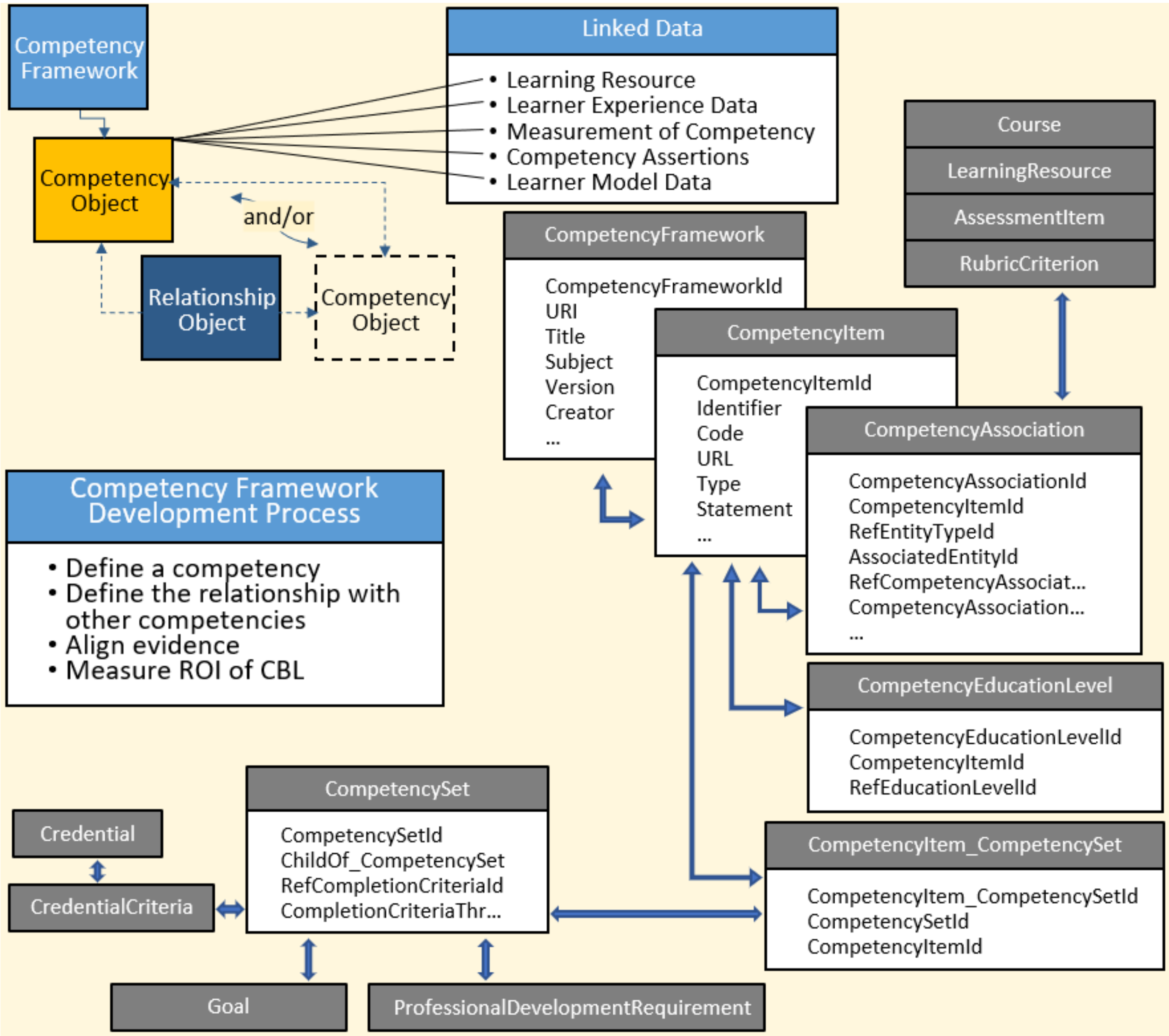

Figure 3. IEEE 1484.20.1 Reusable Competency Definitions.

Interoperable Learner Records

The ADL Initiative supports multiple industry-led working groups, standards bodies, and pilot projects that could enable more expansive DoD access to learner records. Although not commonly thought of as learning resources, learners are the centerpiece of a future learning ecosystem. The shift to lifelong learning requires extensive data about the individual learner to tie everything together. As the demand for personalized analytics continues to rise, it will be critical to consider these types of attributes throughout a learner's life, especially when significant personal or professional events occur that may shift a learner's target pedagogical trajectory.

The current method of learner record management is insufficient for the evolving needs of instructors, learners, and organizations. Today, most academic institutions use a *transcript* to record learners' permanent academic records. Typically, a transcript only includes the most basic of information, such as courses taken, dates, grades received, and degrees conferred from a formal academic institution. Transcripts offer little visibility into individuals' past performance, such as what instructors have noted about them, the informal or nonformal learning they've experienced, and their strengths, weaknesses, and individual needs.

The persistent theme across current efforts is that they limit their focus to harmonizing credentials rather than the distribution and optimization of credentials for jobs. Credentials are issued by a trusted source. There are numerous ongoing efforts like MilGears (United States Navy, 2020), Credential Engine, and Credly that are working towards the development of a credential network that links to credential definitions from numerous trusted sources. Credentials are decomposed into the competencies they represent using CTDL to point to each RCD's universal user ID (UUID). For transferring learner data at the institutional level, credentials are sufficient, and that approach maintains the status quo.

The IMS Global Comprehensive Learner Record (CLR) standard is a promising format for an expanded, more data-rich academic transcript that captures detailed learning experiences and learner achievements such as prior learning, internships, experiential learning, coursework taken and completed, competencies, skills, and co-curricular achievements (IMS Global, 2020). The CLR standard lays the groundwork for contextualizing learning data at the institutional level and enables basic interoperability by allowing organizations to digitally maintain and transfer credentials throughout a learner's career.

The major components of the CLR include information about what the learner learned (e.g., achievements, their relationship to an educational framework, and relationship to other achievements), evidence of their achievement (e.g., assertion, endorsement claim, verification, and artifacts like text, media, and website that provide supporting evidence for the record), and personal information (e.g., address, identity, profile). The tangible result is a web-ready linked-data document that can be shared externally. It supports JavaScript Object Notation for Linked Data (JSON-LD), allowing it to interface with the data ecosystem of digital credentials.

For military training and education in the future learning ecosystem, an auditable chain of evidence is needed for each learner. The overemphasis on credential portability leaves them vulnerable to being devalued, and if an organization relies solely on the accrediting body, there is no mechanism to review the chain of evidence for the credential's conferral. Forensic analyses following any negative impacts on readiness are complicated, especially for credentials that require different learning modalities where behaviors imparted in traditional learning may not always be transferred. Each learner record needs to include a continuous ledger of all learning activities encountered. The activity UUID contained in the metadata, coupled with the associated RCD UUID and a pointer to the evidentiary xAPI data, provides the key building blocks to an analytics pipeline that promotes continuous improvements across all aspects of training and education.

CONCLUSION

As the DoD migrates from legacy data silos to more integrated systems, it must start with the organization and technical structures from the legacy systems. Education and training records of DoD personnel are distributed across a variety of systems and locked into countless disparate data formats. Transport, control, management, governance, and ownership of such data are not easily accomplished—particularly across technological and organizational boundaries. As learning technologies continue to evolve, more and more of a learner's education will take place outside of prescribed classroom settings. It will not suffice to consider only formal degrees and credentials. Therefore, the various systems that hold these learning records must be able to work with each other to form a complete picture of an individual's learning path, including events that have traditionally been difficult to measure and record, such as mentorship, on-the-job training, self-regulated learning, apprenticeships, and so forth.

The research conducted by organizations like the ADL Initiative on metamodel modernization highlights the importance of adopting a DoD-wide metadata strategy that can enable the realization of its big data initiatives. Metadata has already played an integral role in automating labor-intensive processes like course catalog construction and Adobe® Flash® migration, and it has greater potential yet to be realized in optimizing the DoD human capital supply chain via AI-based adaptive algorithms and expanding the breadth and depth of learner analytics. While existing standards cannot support this vision, ongoing work is building upon that foundation to create a metadata strategy that will allow current and upcoming learning technologies to flourish.

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