Measuring Learning Technology in DoD Acquisition

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ABSTRACT

The Department of Defense (DoD) acquisition workforce plays a critical role in assessing, procuring, and implementing emerging technologies to enhance the military's mission readiness. However, a gap exists in evaluating the "learning readiness" that training and instructional technologies have, that are acquired through standard acquisition programs, especially how they contribute to the challenge of *learning transfer*. Technology Readiness Levels (TRLs) and Human Readiness Levels (HRLs) guide acquisition, research and engineering professionals in determining a product's functional and human-use maturity respectively; however, there is no framework to ensure new training and learning technologies are grounded in learning science, best practices, follow current learning technology standards, and have capability to produce empirical data showing how effective and efficient the product is in producing and sustaining required military occupational competence. Meanwhile learning transfer from training to work-performance has shown to be a significant challenge, and produces a virtually undetectable performance gap in units without either mission failure or the necessary data that can both inform and motivate sustainment of the large investment in initial occupational training today. New training systems need to produce this empirical data that supports the detection and management learning transfer gaps in both DoD combat units as well as inform the DoD acquisition workforce what training and learning technology is worth developing. This paper proposes a framework called Learning Readiness Measures (LRMs), that extends the existing TRL and HRL frameworks for supporting future acquisition programs, DoD science and technology research, and for vendors creating training technology and content within new accelerated acquisition timelines.

INTRODUCTION

If one was to visit and inspect the characteristics and use of the various training aids, devices, and simulation systems (TADSS) and their content throughout the DoD today, they would find systems with lots of features or functions that may technically support the task-training and learning they are designed to help with but what you'll rarely find is data on how often, how well, and in what ways these TADSS are being used or the data that show the learning value to the warfighter. In some cases, you'll find training devices stashed away because they're too burdensome to employ, they don't provide enough learning value for the time it takes to use them or because the human-system integration is too difficult to use. Some TADSS will be employed but won't produce any objective data that provides the evidence of the learning produced (i.e., the change in performance). This results in a leadership blind spot as to the degree of learning transfer taking place from the huge investment in initial training received to its actual application and unit mission readiness and/or improvement in the work environment.

What is often the case is that TADSS are developed in a fixed or rapid fashion with no preliminary learning science or learning technology research done to inform what functional features and capability choices are required. Instead, the training technology engineering process focuses mainly on technical feature without any focus on whether those features actually result in improving learning and performance for the target user. Research has a shown an extremely low-level of learning transfer happening that has seemingly slipped through the measures of how effective a training technology is in improving this problem (Saks 2002; Saks & Belcourt, 2006; Bickley et al., 2010). This includes ensuring a training technology is developed based on an optimum concept of employment that ensures maximum learning transfer occurs, and then providing data to monitor this phenomenon in the TADSS target-user environment.

A common challenge with developing training technology for combat system acquisition projects is that training is often the first capability to get chopped when the budgets or schedules get tight. Another challenge is that rarely are TADSS designed to directly support an established training program or to interface with other vendors' systems that can benefit from the data it produces. Instead, requirements for DoD TADSS are often based on slick vendor marketing at trade conferences or based on obsolete curriculum practices or learning science ideas. Most importantly, training requirements lack any data on how effective previous versions of the same technology was in developing the needed mission competence it was designed to produce. The need to improve acquisition technology readiness, produce better outcomes, and better management of technology development isn't a novel problem in DoD, and has been recommended by government accountability office (GAO) reports for decades (GAO 2020; GAO 2019; GAO 2010; GAO 2006; GAO 1999). The main issues we see that limit the ability of today's acquisition professionals and supporting vendors to create training technology and content that maximize its return on investment, are those noted in Figure 1 below.

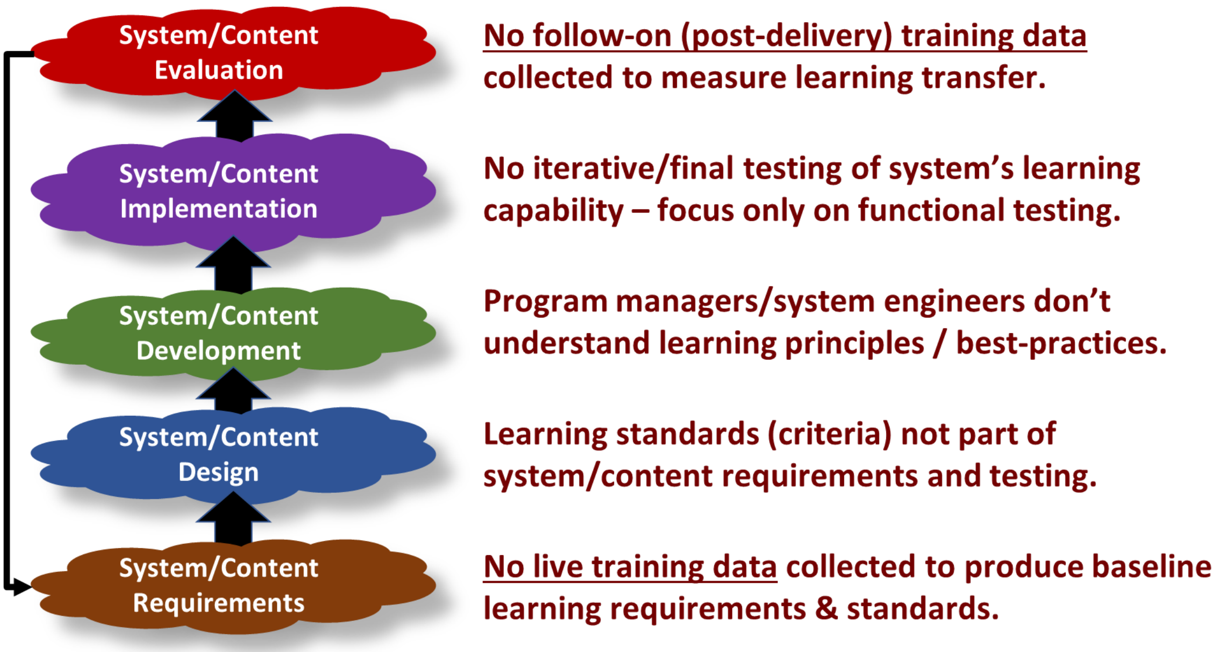

Figure 1. Issues in the Acquisition and Development of DoD Learning Technology and Content.

To address these issues, DoD acquisition personnel need to not only have TADSS requirements based on previous training data – even if only collected in research – but to then have a better understand modern learning science, learning technology standards, current industry and international training best-practices, and the learning engineering process (Goodell & Kolodner, 2023). This requires measures that inform the TADSS acquisition, science & technology, and engineering processes of the effectiveness and efficiency of TADSS before they're fielded. There also needs to be more data made available from preliminary basic and applied science and technology research, as well as empirical data from existing fielded TADSS and their associated training program outcomes; to inform future TADSS requirement decisions.

Today there is also a significant push in government and DoD to use more rapid acquisition strategies like *Other Transaction Authority* (OTA) (Alba & Farinelli, 2025) and *Commercial Solutions Openings* (CSO) to procure and/or build TADSS from existing commercial or research technology in order to get capability to the warfighter faster;

however, this accelerated procurement only exacerbates the challenges noted above, and produces greater risks the TADSS products won't meet value standards needed by DoD users. This is because of the pace at which these methods produce capability without the necessary preliminary learning science and data needed to compare a capability against. This is especially true with vendors that have no experience with DoD users, their high-risk and complex occupations, and the austere environments they must train and learn to work within. Therefore, we will discuss options to support acquisition program managers, researchers, and engineering vendors in order to mitigate these risks and address the above noted challenges.

BACKGROUND

Technology and Human Readiness Levels

Acquisition and system engineering decision support aides have been around for many decades. The current Technology Readiness Level (TRL) definition (Banke, 2010; Manning, 2023) was originally conceived in NASA in the 1970s to provide acquisition professionals and system engineering teams a common measure of technology capability and reliability in order to minimize risk, help make decisions concerning technology funding, and decisions concerning the transition of technology to real applications. In 1989, TRLs gained widespread national acceptance in DoD, the Department of Energy (DOE), and eventually even gained international acceptance in the European Union and International Standards Organization. The TRL levels are indicated in Figure 1 below.

What's missing in the TRLs themselves are measures of how well the technology supports the human-factors of the user. This requires Human-Systems Engineering (HSE) teams to work in conjunction with system engineering teams to ensure that any technology either enhances or compensates for the natural limitations of the human user while employing the technology in occupational environments for sustained period of time. To support HSE role, HRLs are a maturity model designed to support ach of the nine TRLs. The HRL framework is also shown in Figure 2 below. HRLs were initially based on a scale developed at the Sandia National Laboratory but then matured by a 35-member working group from DoD, DoE, Academia, and Industry, and then were formally published by a professional human factors and ergonomics organization (HFES, 2021). While not formally mentioned like the TRLs in DoD acquisition process guidelines, human-system integration is a key stipulated component requirement for which the HRL measures can help inform in a way that is closely coordinated with the TRL measures.

METHOD

Learning Readiness Measures

Learning readiness measures (LRM) in Figure 1 are designed to extend the TRLs and HRLs in order to help acquisition managers, researchers, and engineering teams and vendors to maximize the training and learning value of TADSS (Owens et al., 2025), and to reduce the risk from the other challenges noted earlier, by using the LRMs within a learning engineering process.

The logic of LRMs is that they further add learning focused development measures, in addition to the needed TRL and HRL measures, and necessary instrumentation needed to measure a TADSS resulting learning capability, effectiveness and efficiency across the larger acquisition, research and engineering processes. This logic suggests that first we need TRLs to ensure that the core technology that creates the learning content and stimulus, and provides the architecture that collects data and measures learning outcomes be reliable and stable.

Next, we need to ensure the human-system integration design enables users to focus more on the ultimate learning stimulus and processes, and not having to share limited cognitive or physical resources on how to use the technology or interpret the content it produces. In theory, that now enables the learning engineering process to ensure the latest learning science and data-informed training best-practices available at the time to be incorporated within the training context the TADSS are targeted to support. It should be noted that the LRMs also require that the TADSS is continually tested in the environments where the targeted learner profiles will be, where their attention and method of learning will occur, and to ensure the TADSS learning experience is conducive to learning.

Level		Technology Readiness (Technically Reliable)	Human Readiness (Human Usable/Ergonomic)	Learning Readiness (Produces Long-term Learning)
Production and Life-Cycle	9	Technology/content in-use in operational environment (with use data collected)	Technology data is provided showing non-identified human-system interactions while performing key tasks across multiple live operational environments	Learning system used within institutions, training facilities or on-the-job activity. Longitudinal data demonstrates *learning transfer at/above* competency standards. Data is demonstrated as exportable to refine learning strategy, content, evaluation methods, and standards
Production and Life-Cycle	8	Actual technology/content developed, tested, and demonstrated in operational environment	Human-system evaluation meets key human-factors requirements while performing key tasks with final technology product in live operational environment	Learning system/strategy/content/technology pilot tested as in level 6, at satisfactory competency standards, across several learner profiles. Data is demonstrated as exportable to refine learning strategy, content, evaluation methods, and standards
Production and Life-Cycle	7	Technology/content final prototype demonstrated in a live operational environment	Human-system evaluation meets key human-factors requirements while performing key tasks with final prototype demonstration	Learning system/strategy developed and tested as in level 6, at satisfactory competency standards, across several learner profiles. Data is demonstrated as exportable to refine learning strategy, content, evaluation methods, and standards
Concept Demonstration	6	Technology/content prototype demonstrated / data collected in a live or simulated target environment / conditions	Human-system evaluation using technology in live or simulated target environment / conditions	Learning concept demonstrated, with fully-defined technology / content / objectives and collected data measures, with satisfactory single target user-response, biometric results, and measured evaluation achieved, in laboratory learning environment.
Concept Demonstration	5	Technology/content functions demonstrated / data collected in simulated target environment / conditions	Human-system evaluation using technology functions in simulated target environment / conditions	Learning concept demonstrated, with mostly-defined technology / content / objectives and collected data measures. with satisfactory single target user-response, biometric results, and measured evaluation achieved, in laboratory learning environment.
Concept Demonstration	4	Concept technology/content functions demonstrated / data collected in laboratory environment	Collect part-task performance data to identify ability to perform tasks using technology functions in laboratory environment	Learning concept demonstrated, with semi-defined technology / content / objectives and collected data measures, with satisfactory single target user-response, biometric results, and measured evaluation achieved, in laboratory learning environment.
Concept Research and Description	3	Technology/content critical functional proof-of-concept/principle in a targeted employment task	Basic human factors, usability principles (ISO) standards, UI design requirements identified and incorporated into concept design	Learning science/principles, long-term competency standards, and best-practice training methods are demonstrated as applied to the learning concept for the targeted learner level of competency, learning modality and learning environment
Concept Research and Description	2	Technology/content concept of employment formulated, documented, described.	Concept of user technology employment defined for critical domain tasks / functions, in target environment / conditions.	Concept of learning and evaluation demonstrated – targeted at level 1 needs and gaps. Demonstrates how to assess existing competency measures and standards, how learning will be evaluated longitudinally and laterally using objective data that's reviewable at any time..
Concept Research and Description	1	Technology/content feasibility and principles tested and observed in experimental setting and reported	Existing related technology user performance observed, tasks and required functionality identified, and baseline performance data collected and analyzed	Subject duty/task/content activity and outcomes are measured, observed, performance data analyzed and learning requirements / gaps identified from data. – aka competency analysis

Maturity Level

Instruments Employed

Figure 2: Technology, Human and Learning Readiness Levels.

Similar to TRLs and HRLs, each LRM corresponds to one of the three-phases of any technology development process including: *basic research*, *applied research* and acquisition-based *production*. Like TRLs and HRLs, each of the nine LRMs can be thought of as the necessary "pit-stops" in a multi-cycle race that rises up through the three-phases of development.

At the same time, for cases when rapid development is required (as in OTA or CSO acquisition strategies), notionally some of the levels could be combined or extended to include data and/or decisions that would come in previous or later levels. This isn't to say the LRMs cannot be used in a waterfall model as well but key is that all decisions are based on data-informed results from each measure, and that requires that data from each level feeds back to previous levels, and that the technology is capable of collecting such data as part of its functionality.

Each of the nine LRM milestones enables key learning related capabilities as shown in Table 1 below. These capabilities should be measured and produce the iterative data needed as part of the learning engineering process. These should ensure an accumulating learning capability result at the final LRM9 production outcome.

Table 1. Recommended Learning Readiness Measure Property Matrix

Maturity Phases ->	Basic Research			Applied Research			Production		
Maturity Activities ->	Learning Needs Analyzed	Learning Concept Explained	Learning Science Based	Early Prototyped	Complex Prototyped	Final Prototyped	Development Tested	Operational Tested	Being Applied in real training
Learning System Property Measures	LRM1	LRM2	LRM3	LRM4	LRM5	LRM6	LRM7	LRM8	LRM9
Facilitates long-term learner measurement, tracking, and reporting.								√	√
Exports learner task performance measure data automatically and objectively for further analysis and assessment							√	√	√
Produces and collects task-measure data needed to evaluate learner performance outcome and process			√	√	√	√	√	√	√
Gives trainer and learner involuntary, objective data-informed feedback of performance				√	√	√	√	√	√
Enables trainer to monitor any/all learners in real-time and access all current and past task-measure data					√	√	√	√	√
Adapts learning content and experience to match current learner ability or disposition					√	√	√	√	√
Tracks and measure individual and group/team task measures in real-time and continuously.					√	√	√	√	√
Learning content is instructionally efficient. uses most effective methods and fidelity for target learning environment.			√	√	√	√	√	√	√
Employs statistically reliable psychometric tools, methods, algorithms and data.			√	√	√	√	√	√	√
System learning concept based on latest learning science and learning technology		√	√	√	√	√	√	√	√
System design based on direct observations and measures of target workforce performance tasks, environment, conditions and standards.	√	√	√	√	√	√	√	√	√

DISCUSSION

Learning Engineering and LRMs in System Acquisition

Learning engineering has been mentioned several times so far so should be discussed as far as how its contribution to the acquisition process could be facilitated through the LRMs described above. Learning engineering is an emerging concept, headed by the Institute of Electrical and Electronics Engineers (IEEE), and its sponsored consortium, the International Consortium for Innovation and Collaboration in Learning Engineering (ICICLE) (IEEE, 2025). ICICLE is a project that strives to advance the competencies, tools, design methods and integration within various learning communities and professions, including government and military. There are many references as to its history and its practice and attributes but in general, its aim is to improve the effectiveness and efficiency of any learning resource beyond just media content, including the incorporation of today's rapidly evolving learning science, ever-changing learning technologies and best practices. Another mission of learning engineering is to ensure learning resources are capable of supporting the larger DoD data strategies, as well as using the data as a primary decision-aid at any phase of the acquisition and engineering process. As illustrated in Figure 3 below, learning engineering can be considered an augmentation of other traditional system and human-systems engineering that engineering teams already work with today.

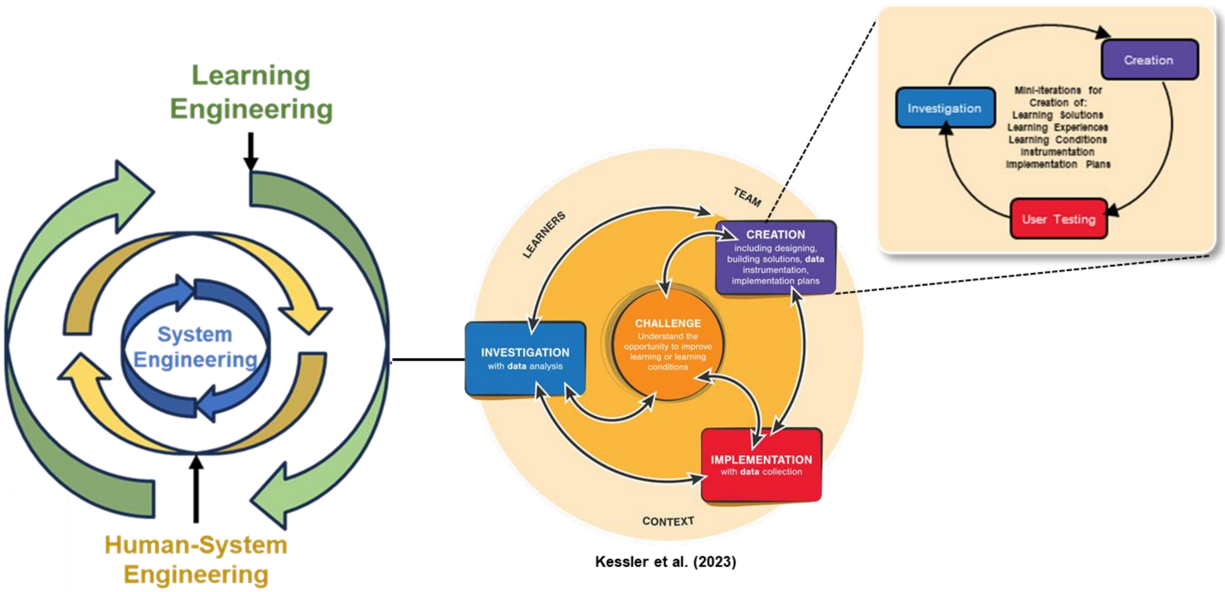

Figure 3. Learning Engineering Process Can Augment Traditional Engineering Practices.

The intent of the LRMs is to influence the use of learning engineering into the larger acquisition, research and engineering process to ensure TADSS actually produces effective and efficient learning value for the targeted users and stakeholders - i.e., the learner, instructor or trainer, training managers and even the training analyst who informs the acquisition requirements in a future product.

Learning Engineering and LRMs in Defense Acquisition University

DAU has been proactively implementing elements of learning engineering within its DoD acquisition learning system, particularly in the implementation of learning technology and the creation, management, and sustainment of learning content. Over the last several years, DAU has been transitioning their online learning assets to incorporate the experience application programming interface (xAPI) technology to varying degrees (currently in over 450 assets). xAPI is a DoD developed data standard that make the sharing of any learning activity and performance outcome data both easy for humans to consume and to share between systems, and to store or retrieve for informing other phases of the learning engineering process. In addition, DAU has extended its use-case of learning engineering by incorporating new traditional and non-traditional learning tools, modalities and delivery mechanisms like Amazon Alexa virtual assistant technology, H5P content collaboration software, incorporating simulation and gamification of learning assets, and using xAPI to collect real-time human performance data-points; data which highlights student areas of struggle and provides learners with early opportunities for remediation. In addition, the collected xAPI data supports the continuous and recursive feedback loops for making learning design improvements, which ultimately leads to engineering better learning experiences, assets and learner outcomes.

DAU has already incorporated many of the discussed LRMs by leveraging xAPI data as the driver for engineering new learning technology and content, and implementing a maintenance business processes called *short cycle reviews*. DAU's learning engineering team consists of Instructional Systems Designers and Learning Asset Owners who collaboratively engage in these short cycle reviews by asking key questions within five-areas of focus, and which change based on different time-frames over the period of a year.

Time Frame: 0-3 Months
This phase focuses on setting a strong foundation by asking questions aimed at identifying immediate issues, establishing baseline data, and to guide early improvements. As an example:

1. Learner Engagement:
    - Which learning activities have the least engagement, and why?
    - Are learners dropping off at specific points in the asset?
    - What is the average time spent on each module?
2. Learner Performance:
    - Are learners consistently failing specific quizzes or activities?
    - How does the time taken to complete activities compare?
    - Are learners achieving initial learning objectives/passing the exam?
3. Learning Pathways:
    - Are learners skipping/testing out any steps in their pathways?
    - How do learners navigate through the asset—linear or non-linear?
    - Are alternate pathways being used, and how successful are they?
4. Resource Utilization:
    - Which resources are underutilized or overlooked?
    - Are learners revisiting resources?
    - How frequently are learners accessing supplementary materials?
5. Predictive Analysis:
    - Can low engagement or performance in early activities predict dropout?
    - Are there learner behaviors indicative of early success?

Time Frame: 4-6 Months
At this phase, patterns begin to emerge so questions begin to focus on understanding mid-term trends and evaluating the impact of content and the initial changes made. Examples include:

1. Performance Scores: Tracking scores below 80% to identify areas needing improvement.
2. Outlier Identification: Visualizing data to identify outliers and target areas for further investigation.
3. Item-Level Analysis: Conducting item-level and object-level analysis to inform design choices and enable quicker updates.
4. Design Impact Analysis: Analyzing the impact of design choices on learning outcomes, particularly focusing on question type, setup, wording, and placement.

Time Frame: 7-12 Months
This phase focuses on more long-term evaluation of learning services, refining learning strategies, and aligning them with organizational goals. Questions now focus on exploring sustained learning trends and outcomes. Examples include:

1. Cyclical Performance Trends: Analyzing performance data over a minimum of six months to account for cyclical influences.
2. Impact Validation: Validating the impact of mid-term adjustments and remediation efforts on performance and engagement metrics.
3. Refinement of Item-Level Analysis: Conducting item-level and object-level analysis to inform design choices and enable quicker updates in learning asset life-cycle.

4. Engagement Metrics: Tracking engagement metrics such as time spent, success rates, and return rates to measure the effectiveness of learning assets.

Instrumentation for Learning Engineering and LRMs

A key element in learning engineering and LRMs is the need to design and employ a data implementation pipeline shown in Figure 4 using both raw input from the TADSS themselves, and the use of learning measurement instruments, to collect data and measure human autonomic learning effectiveness and efficiency (Van Gog & Paas, 2008).

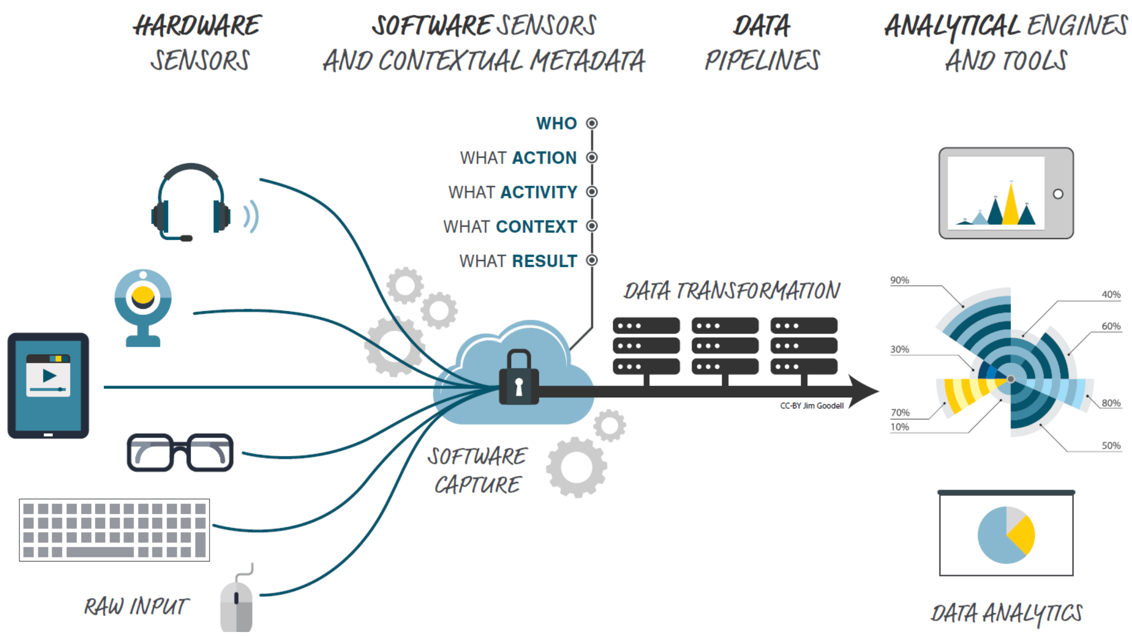

Figure 4. Learning Engineering Data Pipeline Concept (Goodell et al., 2023)

A similar data pipeline concept has been successfully created in research for the US Army (Figure 5) using its open-source adaptive instructional system, and has been found to be a critical asset in learning engineering by testing the early stage learning concept and science the learning technology is based on but collecting critical data needed to make other design and development decisions. This *instrumented learning assessment architecture* produces xAPI data based on predefined competencies the technology needs to develop, and objective evaluations provided by configurable algorithms - that are themselves updated from the same data.

The architecture is capable of importing low-level data directly from both the simulation or media-based content and technology itself, and has capability to assess biometric data directly from the targeted trial-learners used in the learning engineering process. Research has shown that various learning physiology attributes can be measured using modern instrumentation like those shown in Figure 5 (Giannakos et al., 2020). These measurements can reveal important learning information beyond the common measures of performance outcome such as accuracy, precision, latency, or errors made. Combinations of behavioral, cognitive, and emotional measures can provide information concerning the internal human learning processes, in terms of both the desired effect and cognitive affect from a learning experience.

Based on this idea, studies have focused on minimizing cognitive load factors competing with the human learning processes (Van Merrienboer & Sweller, 2005). Research also focuses on what is called *orchestration load*, which is the effort necessary for the trainer or learning facilitator to conduct learning activities using technology-based learning activities and learning processes (Prieto et al., 2017). The idea is to measure the degree of mental effort a technology or content requires to be invested in by both the learner and the teacher during a learning activity. By using instruments, learning scientists and learning engineers can determine what features and content formats minimize a learner's non-effective cognitive effort called *extraneous cognitive load* – load that distracts from the learning process. Instrumentation can also inform learning engineers on which formats maximize what is called *germane cognitive load* or effort that enhances the learning process such as providing learners useful prompts or solution steps on-demand with tutoring based features.

Research has also found instruments that reveal physiological data that can detect the quality of a learning experience with good accuracy - e.g., heart-rate, electrodermal activity, skin temperature, and blood volume pressure (Giannakos et al, 2020). This includes using pupillometry through eye-tracking instruments, that can predict post-learning recognition memory strength (Kafkas & Montaldi, 2011).

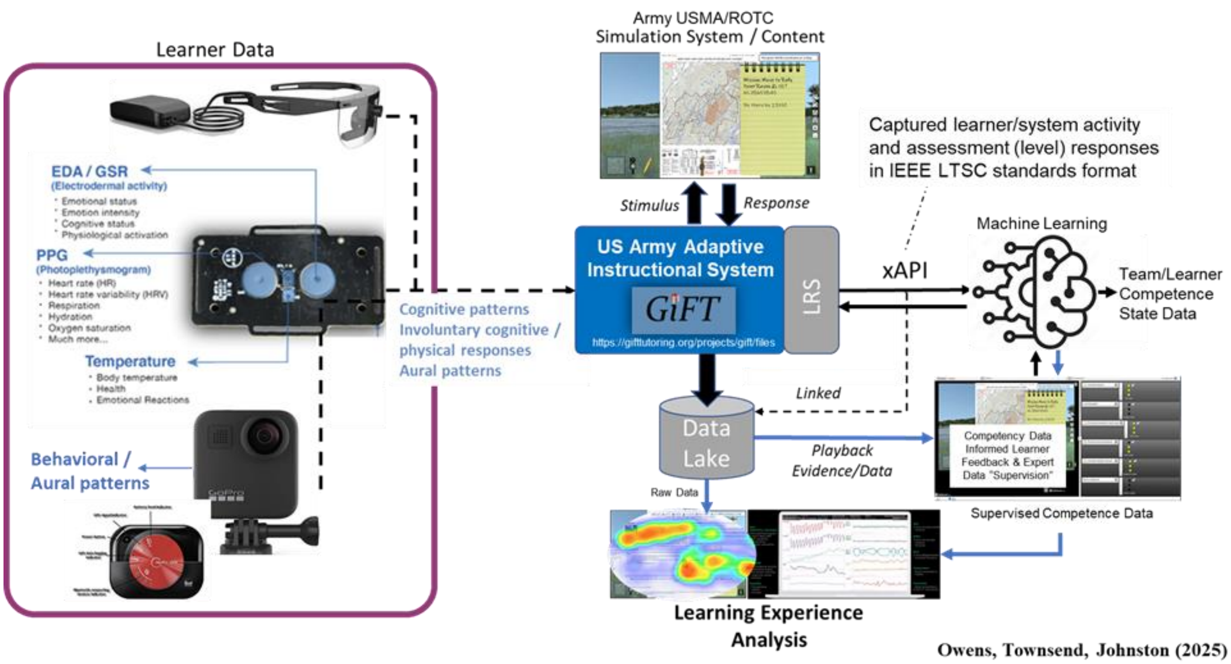

Figure 5. Instrumented Learning Assessment Architecture

As shown in Figure 2, we've recommended that certain LRMs include such instrumentation while testing new TADSS, to assess the targeted learner's involuntary physiological responses as well as using these same instruments to collect data that support corresponding HRL assessments. In this way, the LRMs and HRLs, with associated instruments, could reduce the risk of a new learning resource not being usable or contributing to low learning transfer from the training environment to the real work environment. Such data could even provide the acquisition professional with more quantitative data on how a learning technology provides learning value to the military or government user.

Learning Standards for DoD Learning Technology

Using data like the xAPI protocols mentioned in the DAU use-case above is important but for this data to be meaningful in terms of measuring a new DoD TADSS learning feature's effectiveness and efficiency, there must be specific learning objectives and standards to measure those properties against. In DoD, training standards should stem from the same ubiquitous mission essential task lists (METL) used by every service. Mission essential tasks (MET) are defined based on a military unit's specific set of missions it's been provided equipment and manpower to perform. METs are supported by various unit-level tasks that break down each task to the various echelon teams and team-roles who actually execute the mission activities that can be measured. These tasks inform multiple phases and types of military training, from basic classroom familiarization training up through live culminating combined-arms combat training exercises, and ultimately employs the specific TADSS the acquisition process provides to support this training.

We submit that these METs should be used as the targeted training objectives and standards used in both DoD capability requirements and used with LRMs as the standards to measure how well TADSS actually provide their learning capability. LRMs would ensure these tasks are part of the learning engineering investigation, creation and implementation processes, and improve the measures themselves by ensuring that TADSS produce the raw activity data (like xAPI) to directly support how each standard is measured, as evidence of how effective and efficient learning occurs, to support larger DoD data strategies, and future TADSS capability requirements and acquisition decisions.

CONCLUSION AND RECOMMENDATIONS

We discussed a gap in the current acquisition, research and engineering processes when procuring new TADSS technology and content for DoD: development without any measure of the TADSS data-informed ability to actually produce and maximize learning. This gap includes not having any regular requirements to ensure all TADSS are capable of producing inspectable and exportable learning activity and data (not just result) as evidence of the end-users training value.

We discussed how the risk of low-value TADSS will only become greater with recent government policies that direct the use of OTA and CSO acquisition methods to rapidly procure DoD capability (like TADSS) without measures of maturity based on modern learning science, and data-informed training best-practices. Therefore, we recommended a framework of *learning readiness measure* (LRM) that would help acquisition professionals, researchers and engineering teams to ensure the TADSS they create for DoD have capabilities and produce evidence that provide their learning value to training users and stakeholders. These LRMs would extend the existing TRL and HRL measures that are used today to mitigate the risk of procuring immature technology and/or poor HSI design respectively. We submit that LRMs will provide a simple set of measures that inform acquisition managers, researchers and engineers, who today usually have little to no expertise in learning science, training best practices, or the expertise in learning technology, when developing future TADSS, and will also more easily influence the integration of the learning engineering process into DoD acquisition, research and engineering of new TADSS based technology and content.

We discussed the IEEE sponsored learning engineering process and how it could be integrated, through LRMs, in DoD acquisition, research and engineering processes. We also provided a use-case of how the Defense Acquisition University (DAU) is already employing learning engineering practices and activities similar to LRMs in improving its own training and learning capabilities for future acquisition professionals. We recommended the use of modern biometric cognitive or behavioral instrumentation that research has shown can provide many kinds of data-informed evidence of learning effectiveness and efficiency occurring with new TADSS. Finally, we recommended that as part of future DoD TADSS acquisition requirements and engineering developmental and operational testing, while using LRMs, that the DoD METLs and their enabling sub-tasks and measures, should be used as the standards that TADSS must demonstrate their learning value with.

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