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Learning Science Executive Summary

For Strategic Leadership

*“In this competitive environment, the Department must pay much more attention to future readiness, and regaining our Joint Force conventional overmatch over time...We must also be prepared to deal with technological, operational, and tactical surprise, which requires **changes to the way we train and educate our leaders and our forces**, and how we organize for improved Departmental agility.”*

- James Mattis, Former U.S. Secretary of Defense, Monday, June 12, 2017.

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Introduction

Across DoD there is a growing demand signal to optimize personnel's processing speed, agility, and comprehension. Individuals must learn to thrive in volatility and complexity, think in terms of system dynamics, and apply strategic understanding of complex systems and the far-reaching effects of actions taken within them—even to seemingly lower echelon and tactical actions. Organizations must learn to shift and grow with evolving needs, rapidly capturing and integrating lessons learned and disseminating new ideas across their enterprises. To meet such demands, the DoD must embrace continuous learning, find more efficient ways to develop and maintain relevant knowledge and skills, and develop reliable feedback loops that ensure our systems remain relevant in an ever-changing environment.

In short, individuals require a greater breadth of interdependent knowledge and skills, at an increased depth, and these competencies must be acquired at a more rapid pace.

While much attention has been dedicated to *what* technology solutions or organizational mechanisms are needed, significantly less has been focused on *how* to use such systems to achieve reliable enhancements to human performance and, ultimately, to improve overall readiness. In response, **this report summarizes a review of not-yet-exploited learning science principles for optimizing human capabilities**. It includes eight research-supported recommendations for DoD.

Learning science provides a guiding set of rules that help optimize learning experiences, trajectories, time, and impact.

What is Learning?

At its most foundational level, learning is any change in long-term memory that affects downstream thoughts or behaviors. The concept of learning applies across performance domains, not only to cognitive development. It necessarily includes physical and emotional aspects, as well as inter- and intrapersonal, social, and cultural components. Certainly, learning occurs in formal settings (e.g., a schoolhouse or training exercise), but it also happens in self-directed, just-in-time, social, experiential, and other informal ways. These varied experiences accumulate in long-term memory and, fused together, affect how we respond to the world.

Learning science draws from many scientific disciplines, including cognitive science, neuroscience, education, anthropology, design science, computer science, data science, and even applied linguistics. Broadly, it integrates these disciplines to understand how people learn,

the factors that affect learning, the instructional methods to enhance learning, the technologies to facilitate learning, and the methods to evaluate it.

Learning in the Future

The 21st century is marked by significant technological progress in every field. For learning and development, these advancements have helped us realize the promise of “anytime, anywhere” learning as well as learning personalized to individual needs. Emerging capabilities are providing transformative possibilities: facilitating customized learning at scale, optimizing learning systems in response to large and diverse data sets, and enabling evidence-based talent management across organizations. The landscape of learning has broadened, now encompassing the full spectrum of experiences across training, education, and development. Age, rank, and traditional degrees are being replaced by experience and applied expertise as markers of capability. Performance-based credentials, including competency badges and micro-certificates, are taking the place of transcripts to document individuals’ traits, talents, skills, knowledge, preferences, and experience. These shifts, in turn, are disrupting conventional developmental trajectories and raising the ceiling of what individuals and organizations can achieve.

The future of education and training is a holistic, lifelong, personalized paradigm that contrasts with the Industrial Age model of time-focused, one-size-fits-all learning.

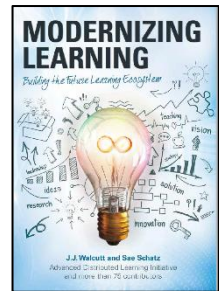
This so-called *future learning ecosystem* promises to substantively change the way we learn, moving away from old models of disconnected, disjoint experiences to a connected continuum of lifelong learning, personalized, driven by data, and delivered across diverse locations, media, and periods of time. However, while technological advancements can create this “internet for learning,” learning science needs to define how we optimize its use.

Recommendations

Many existing instructional theories already articulate well-documented best practices for supporting evidenced-based teaching and testing. The National Academies, for instance, has published two highly acclaimed volumes, [*How People Learn I*](#) and [*II*](#), that describe specific instructional tactics and considerations, such as how to design classrooms or better facilitate memorization. Other federal organizations, from the Department of Education to the Office of Naval Research, have also invested in learning science efforts, for instance, to identify the most effective ways to teach children to read or to translate teaching best-practices into military instructor manuals. Also, several well-known models, including as Robert Marzano’s *9 High-*

Yield Instructional Strategies and Rich Mayer’s *12 Principles of Multimedia Learning*, provide direct guidance for conventional training and education contexts. DoD could benefit from the broad and more consistent application of any of these existing bodies of work. However, all of these currently available recommendations focus on single learning experiences and miss the opportunity to enhance learning systems more strategically and longitudinally. In doing so, **current applications fail to achieve the potential afforded by new technologies, which allow us to facilitate learning anywhere and anytime, to constantly build personal development, and to manage with precision and organizational agility.**

To achieve human performance optimization and overmatch, therefore, we need to widen our perspectives. It is not enough to incrementally improve the current system—simply doing what we already do but at a slightly higher quality. Further, DoD needs to also consider enterprise-level transformation of its entire integrated talent development system. The section below outlines strategic recommendations that address this goal. Related recommendations outside of the scope of learning science, such as for supporting technologies or policies, are excluded here but are available in the larger *Modernizing Learning: Building the Future Learning Ecosystem* report.



1. Develop, assess, and value 21st century competencies

“There’s a foundational set of cognitive, intrapersonal, and interpersonal skills that provide the flexibility, adaptivity, and capability people need to navigate through the kind of constant change, discontinuous, and sometimes irrational situations that pervade the 21st century. Education should focus on that, much more than it has in recent years, because if we don’t make that shift, we’ll develop a very brittle set of people at a time when adaptability will be core for their survival.”

— Christopher Dede, Ed.D., Harvard University

Personal characteristics, such as good judgment and social awareness, have always mattered. Increasingly, however, automation driven by artificial intelligence, ever-increasing computing power, big data, advanced robotics, and the proliferation of low-cost advanced technologies are the shifting nature of work, along with the organizational dynamics of military operations, business, and government. Technology is replacing the physical and intellectual tasks of many specialties. Memorizing procedures, calculating solutions, and even synthesizing diverse information into novel forms are fast becoming the purview of computers. Meanwhile human work increasingly focuses on social and cultural factors, creativity and creative problem-solving, digital literacy and technology partnership, and rapid adaptability.

Modern core competencies tend to emphasize higher-order, more nuanced and sophisticated capabilities instead of fact-based knowledge or procedural skills. Similarly, where in the more recent past, highly skilled professionals typically advanced by focusing on narrow disciplines, today's savants are often "expert generalists" able to synthesize across disciplines, learn new concepts and contexts rapidly, and adapt to changing conditions. **DoD needs to open its aperture to this expanded set of competencies, to include articulating their characteristics, actively seeking to develop them, assessing them, and valuing their achievement (for instance, in selection and promotion processes).** This recommendation applies, not only to specialist occupations or higher echelons, but broadly across the Department.

2. Prepare personnel for information overload

Modern communication and information technologies enable constant connectivity, giving access to just-in-time information, finding and engaging experts from around the world, and making unprecedented amounts of data available. Yet, there is a cost to this increased speed: It is driving the need for rapid and continuous learning to keep pace with constantly changing conditions.

Most importantly, **greater access to all of this information does not directly translate into greater comprehension.** In fact, the opposite is often true: Individuals struggle with information overload, which creates dramatic (and potentially dangerous) cognitive biases, such as deferring to negative options or disengaging from decisions, allowing anxiety to have an undue influence on decisions, and focusing on only the most obvious or familiar information while ignoring other relevant details. Data abundance can lead to information chaos and cognitive overload.

Learners need new supports that help them filter out "noise" and meaningfully integrate the relevant "signals." If not addressed, DoD runs the risk of increasing information acquisition but reducing deep comprehension and knowledge construction. Thus, **we must consider learning science techniques to help personnel filter and connect information meaningfully.** The most relevant recommendations include developing individuals' self-regulatory abilities (specifically related to cognitive overload), factoring overload into the pacing and delivery of learning episodes, and integrating ongoing assessments that can provide early warning indicators of overload in learning and performance contexts.

3. Teach and support self-regulated learning skills

Learners must be afforded enough autonomy to remain engaged, construct their own knowledge and skills, and develop their self-regulation abilities

As we progress towards a more chaotic and data-saturated world, self-regulated learning skills, or the ability monitor and motivate oneself in learning, will become increasingly important. Learning in the future will not only rely on one's ability to learn provided material but rather the ability to seek out, determine accuracy and relevancy of information, and then assimilate it into long-term memory in a manner accessible and translatable to the real world. Successful self-learners do a lot more than study and memorize information. They stay alert and are curious to discover new, valuable learning. They skim a lot of content to find the important points. They search informally to nurture motivation for intensive study, and periodically review afterwards to fight forgetfulness. And, they find the time to do it all. Ultimately, self-regulated learning skill accounts for 17% of learning outcomes.

Although more than 70% of work-related learning is self-learning, many individuals have never fully developed their self-regulation abilities. Ideally, technology will reduce the difficulty and friction of self-learning activities, while making it easier to learn in small slots of available time. Learning science can help inform how these technologies function, for instance, the intervals to use with micro-learning or models for implicit or explicit feedback. Learning science principles can also inform the development of self-regulation mindsets and skills. Key recommendations include using assessments to personalize support for self-regulated learning skills and mindsets; building confidence, self-efficacy, and internal "locus of control" about learning; develop goal-setting and planning skills; activating prior knowledge to enrich self-regulated learning strategy use; support metacognitive, or self-reflection, skills; and fostering habits of post-learning reflection.

4. Recognize and better facilitate informal learning, such as social learning

There's a popular notion called the 70:20:10 model. It estimates that around 70% of learning is informal or on-the-job, about 20% involves peer and social learning, and only about 10% is formal training and education. While this model is merely a general concept, not a firm quantitative rule, it helps underscore the importance of surfacing informal learning—i.e., the 90% of learning that occurs outside of formal settings. As already mentioned, self-regulated learning skills can help optimize the value of informal learning, particularly for the 70% that occurs on-the-job. To complement this, DoD can also employ social learning methodologies.

Where formal learning is directed and designed by an organization and provided to its personnel, social learning is a story largely written by the learners, themselves. It is often

untidy, diverse, and deeply personal, as people bring their own perspectives and experiences into the learning space. When managed effectively, organizations can integrate both formal (system, process, hierarchy, control) and social (creativity, subversion, innovation, amplification) mechanisms. More than just enhancing learning, the best of these programs creates organizational resilience and adaptability and reduces the risks of stagnation and operational surprise that often impede effectiveness in hierarchical bureaucratic organizations. Social learning methods have been demonstrated in business settings, and such programs can be nurtured for the Department as well, as a meaningful supplement to other formal endeavors.

5. Make assessments more learner-centered, developmental, and integrated

You can't manage what you don't measure.

Too often in the current system assessments are used primarily as accountability tools (e.g., to ensure a student completed the assigned reading or that a trainee meets the required physical standard). We also tend to use high-stakes, one-shot tests, often set in unrealistic contexts (a paper-based test rather than applied performance measures). Finally, we sometimes do a poor job of measuring the actual phenomena of interest (learning outcomes), instead resorting to easier measures that serve as poor-quality proxies (time spent in class). In contrast, useful assessments have several key characteristics: They provide serviceable feedback, promote learner development, and use meaningful evidence-based methods in real-world settings.

Feedback: At the most foundational level, quality feedback should enable an instructional system to understand what was learned and what was not while simultaneously providing learners and organizations data to clarify how they can improve their processes. Assessments used primarily for accountability, oftentimes fail to provide the recommended actions needed for individual and/or organizational growth. In contrast, “learner-centered” assessments provide feedback in a manner that clarifies what the learners need next, emphasizing personal development, and treat measurement as a continuous improvement process rather than a single event.

Integrated: A rhythm of assessments (without over-monitoring) should be developed in forms more closely resembling integrated operational assessments, stealth assessments, portfolio evaluations, and experiential trials should be considered. Significant attention needs to be paid to understanding new ways to prove capabilities beyond the current forms of assessments, articulation of grades, or standardized testing methods.

Learning Analytics: By analyzing an individual's behaviors, as revealed by data captured through the integrated assessment methods, we can start to better understand their attitudes

and capabilities in ways unimaginable with legacy assessments. However, we need to ask the right questions, and be able to identify appropriate, developmentally focused remediations in response to the data. While data science and artificial intelligence (AI) might enable these learning analytics, learning scientists are critically needed to guide those capabilities to a useful target.

6. Use personalization and mastery learning to optimize outcomes

Improved measures and analyses can help the Department identify individuals' strengths and weaknesses, and it can use that information to personalize learning and development.

Generally speaking, personalized learning attempts to create different experiences for different learners or for the same learner at different points in time. When instruction is personalized, learners show improved recall and better near- and far-transfer. Personalized learning can engender deeper understanding as well as hone higher-order cognitive skills, such as leadership and adaptive thinking. Personalization is often best when combined with mastery learning, with a focus on holding consistent performance standards and allowing the developmental trajectories (time, learning approach) to vary.

Customized experiences, like those a skillful tutor might craft, are the gold standard for learning. But these do not scale well, given the costs and limited availability of expert teachers and trainers. Computer-assisted instruction can mitigate scalability issues, and personalized learning technologies can (at least partially) unlock the benefits of one-on-one learning, similar to working with a personal mentor. The average rule is that adaptive learning technologies produce one-third more effective outcomes or are one-third more efficient than conventional methods; however, some systems, such as DARPA Digital Tutor which produced outcomes around five standard deviations better than status quo methods, have far exceeded these benchmarks.

7. Employ system-wide strategies to long-term, big-picture effectiveness

Provide strategy support for immediate activities, broader experiences, and lifelong learning arcs

Explicit in the learning ecosystem concept are the notions of diversity and interconnectivity—across an entire lifetime (or, at least, career). Instructional designers need to broadly consider multiple and varied learning modes and, importantly, how to help connect learners' experiences across them. Currently, most learning theories focus on constrained learning experiences, such as a single class, using a single delivery modality, focused on a single subject.

DoD needs to consider learning at different abstraction levels and across more diverse elements: To not only help plan the immediate activities (micro-level interventions), but to also design broader programs (macro-level interventions) and optimize lifelong learning (meta-level interventions). We need to help learners aggregate and make sense of learning experiences across devices, modalities, episodes, and learning dimensions—beyond the context of a given course or training event, across their holistic lifetimes of learning.

Relatedly, we must avoid the temptation to simply optimize each individual learning episode, without consideration of their integration into a collective tapestry. For example, consider the just-in-time training—such as what a Sailor might receive through the Sailor 2025 initiative. On the one hand, this method helps avoid inefficient massed learning, where individuals often wastefully forget much of what they learned. On the other, it risks creating disjoint learning that individuals struggle to meaningfully integrate into the long-term memory schemas and does not comprehend beyond a superficial level. There is nothing inherently wrong with just-in-time learning; rather, the point is DoD needs to consider system-wide learning strategies that balance holistic efficiency and longitudinal performance effectiveness against local optimizations. If the DoD allows each course, program, school, or command to develop local optimums in isolation, we risk creating an overall inefficiencies and ineffectiveness. Strategy—informed by learning science—must be applied to, and integrated across, all levels.

8. Integrate with the wider social/technical/organizational system

Integrating new learning science methods is not enough to achieve maximal benefits; it is necessary to also harmonize these advancements with other, interdependent parts of the larger system:

Technological Infrastructure – Information technology forms the enabling foundation combining instructional systems, interoperability standards, cross-platform data integration, and centralized software services. It will allow learning to become pervasive—accessible anytime, anywhere, in many forms, and for many functions; and accordingly, learning can be tailored for optimal effect.

Human Infrastructure – This vision depends upon a highly skilled human infrastructure, who can design, deliver, and facilitate learning. New skills in learning technology, learning-focused data science, and strategic learning methodologies will be needed, and new disciplines, such as learning engineers, will need to be defined, developed, and supported.

Design – Learning designers will need to understand how to differentially apply diverse technologies, blend disparate delivery modalities into holistic experiences, build-in and apply learning analytics, balance practical logistics against learning outcome criteria, and incorporate learning and development into personnel and workforce systems.

Governance – Enhanced learning experiences require organizational coordination, technological interoperability, and the aggregation of data across boundaries. Governance structures are needed, not only between DoD offices but also across public-private boundaries and diverse federal programs.

Policy – Policies and guidelines are needed to guide the implementation of learning science across DoD, as well as the use of learning technologies, collecting and employing learning data, and related usage concerns, such as on data privacy, coordination across functional areas, and acquisition guidance.

Commitment – The benefits of the future learning ecosystem can only be realized through their gestalt; that is, when all of the parts come together in concert. Strategic oversight of the larger talent management system along with performance metrics (for the system, itself) are needed at this holistic level.

“We’re interested in outcomes. I want effective learning. I want measurable learning. I want learning that results in combat capability. That’s what we’re looking at in terms of learning science, from our perspective inside the Pentagon.”

– C. Fred Drummond, Deputy Assistant Secretary of Defense for Force Education and Training

Appendix - Introduction

Increasingly, military personnel are expected to learn continuously and develop new capabilities across their entire careers in an atmosphere of volatility and complexity. They must develop deep understanding, across a range of cognitive, affective, interpersonal, and physical competences, and refresh those capabilities as situations evolve. As they progress to a more chaotic and data-saturated world, they're expected to independently seek out and determine the accuracy of new information and to assimilate new knowledge in ways that are rapidly translatable to the real world. For these reasons, Defense leaders have created a demand signal for deeper understanding of learning science, to optimize cognitive processing speed, agility, and comprehension.

Technological advancements now offer AI-driven learning, data analytics, the ability to better measure behaviors or knowledge, foster growth, and make personalized interventions. However, while much attention has been dedicated to *what* technologies can assist in this situation, significantly less attention has focused on *how* to best utilize those systems to improve readiness. Learning Science provides a guiding set of rules that help us optimize learning experiences, trajectories, time, and impact.

This document provides examples that help demonstrate uses of learning science, for possible application in military programs.

The examples in these appendixes coincide with the *Learning Science Executive Summary*. It outlined recommendations for DoD learning science innovations, in these eight areas:

- (1) focus on developing and accessing 21st century competencies
- (2) prepare personnel for information overload
- (3) teach and support self-regulated learning
- (4) support informal learning such as social learning
- (5) enhance assessment
- (6) use personalization and mastery learning
- (7) develop learning strategies (not only local point-to-point solutions)
- (8) plan for other interdependent elements such as technology and policy considerations

Appendix A - Recommendation 1: Develop, assess, and value 21st century competencies

Developing and maintaining 21st century competencies means that individuals develop a greater breadth of interdependent knowledge and skills, to include intra- and interpersonal capabilities, higher-order cognitive skills, metacognition, and psychophysical abilities.

SWEG-A Human Dynamics & Performance (HDP)

SOURCE: LTC Phillip Thomas (Phillip.thomas2@socom.mil)

DESCRIPTION: The Special Warfare Education Group (Airborne) has established a program for holistic human development, which has had a dramatic impact to the rate of Special Operators completing their qualifications. Some of the interventions under this program include:

- **Special Operations Cognitive Enhancement for Performance (SOCEP):** The highest SOCEP users experienced lowest stress and highest performance, and Rangers who completed a SOCEP workshop outperformed other students by 25%.
- **SFARTAETC; Tactical Human Optimization:** Students who completed SFARTAETC reported 80% less stress and performed with greater accuracy compared to their peers.
- **Rapid Rehabilitation, and Reconditioning (THOR3):** The THOR3 program focuses on healthy and efficient mind and body education. Exposure to THOR3 reduced the school's average recovery times, from 44.3 days to 34.5 days. It also reduced incoming students "elevated risk for injury" from 5 in 10 students down to 2 out of 10.
- **Human Engagements & Adaptive Thinking (HEAT):** HEAT teaches interpersonal skills while under stress. Before its introduction 25-33% of students per class had to recycle (start over from the beginning) or were relieved from the training because of lack of interpersonal skills. HEAT drastically reduced the recycle/relief rate, for instance, from a 25% passing rate after recycling for the Special Forces Q Course to an 88% passing rate after recycling with HEAT training.

DARPA Strategic Social Interaction Modules (SSIM) "Good Stranger" Program

SOURCE: <https://www.darpa.mil/program/strategic-social-interaction-modules>

DESCRIPTION: The DARPA SSIM program sought to improve the understanding and development of interpersonal skills, particularly for cross-cultural contexts, using novel training techniques such as experiential simulations. It was nicknamed the "Good Strangers" (GS) project because its mission was to train warfighters to successfully manage social interactions in high-risk and consequential situations using *human dynamics proficiencies* (HDPs) and cross-

cutting skills. HDPs include (re)initiate encounter, make sense of the situation, repair or recover, appraise outcome, pursue objectives, and (re)plan. Cross-cutting skills include attending to non-verbal cues, perspective taking, mutual attention, rapport and trust building, self-control, self-awareness, and recognizing social affordances.

One study in the program tested “Stealth Training” as a method for developing HDPs in instructors and students in an Army course. Stealth training involves using an expert in a course not specifically teaching GS skills (e.g., land navigation) to model GS behaviors during train the trainer sessions. Data from observer ratings of all instructors showed that **Stealth-trained instructors’ mean scores for HDP behaviors during instructor-student interactions were 52% higher than those who received traditional training.** Also, students in the study participated in role-playing exercises before and after they received Army training with either Stealth trained or traditionally trained instructors. Students receiving training from Stealth trained instructors performed significantly better in earning trust with civilians, demonstrating a respectful demeanor, and remaining engaged during social interactionsⁱ.

RULER

SOURCE: <http://ei.yale.edu/ruler/ruler-overview/>

DESCRIPTION: The Yale Center for Emotional Intelligence developed RULER as an evidence-based educational framework to teach emotional intelligence skills – Recognizing, Understanding, Labeling, Expressing, and Regulating emotions - in schools. Research on RULER indicates students have better academic performance and it improves school climate.ⁱⁱ

In 2013, Yale partnered with the Air Force Research Laboratory (AFRL) to translate RULER for DoD purposes. The objective of the program was to improve trust and optimize reliance on autonomous systems by developing deeper understanding of inherent social cognitive underpinnings of Human-Machine Teams (HMT). RULER already has a large empirical base for performance, behavioral, attitudinal, and other social and emotional improvements in K-12 and workplace settings.

This research program will extend findings to military and HMT contexts to simulate an intelligent machine partner and develop an understanding of how users perceive and respond as they interact with the machine. Multiple lab and field studies continue to be conducted to produce two expected outcomes. First, studies will give insight into the risks and benefits associated with the social/emotional side of HMT. Second, a proof of concept will be developed for targeted methods to optimize HMT interaction and performance through user training and interface design.ⁱⁱⁱ

Collaborative for Academic, Social, and Emotional Learning

SOURCE: <https://casel.org/>

DESCRIPTION: The Collaborative for Academic, Social, and Emotional Learning (CASEL) is a not-for-profit organization dedicated to enhancing social and emotional learning. It recommends a more robust model that integrates intrapersonal, interpersonal, and cognitive competence. CASEL has developed and tested formal support and education programs that can be replicated. They focus on five key areas that encompass various behaviors, mindsets, strategies, and skills:

- Self-awareness, such as accurate self-perception and self-efficacy
- Self-management, for instance, impulse control
- Social awareness, including empathy and respect
- Relationship skills, such as teamwork and communication
- Responsible decision-making, including reflection and ethical responsibility

The program improved academic performance: 11% higher, there was *greater* motivation to learn with a deeper commitment to school, and fewer reports of student depression, anxiety, stress, and social withdrawal.^{iv}

Making Good Instructors Great

SOURCE: Schatz, Burley, Taylor, Bartlett, & Nicholson, Making Good Instructors Great: 2012 Project Summary Report

DESCRIPTION: The Making Good Instructors Great (MGIG) project specifically focused on developing methods and tools that instructors could use to build military personnel's cognitive-readiness skills. MGIG consists of three components:

1. Robust instructor competency model^v
2. Suite of knowledge products to build mastery:
 - a. Instructional tactics and assessment techniques handbook
 - b. Corresponding tactics and assessment techniques pocket guide
 - c. Corresponding DVD with additional support media
3. Instructor development curriculum including a student activities journal for the course

A beta test of the MGIG course was held at Camp Upshur, Quantico, VA in 2012 with 56 Marine Reservists participating as students. Student rated the course positively, averaging 4.37 out of 5. Analysis of learning outcomes revealed overall performance increases of 26.4% from pre-to post-test and a 185% increase in comprehension specifically.

OECD Learning Framework 2030

SOURCE: Organisation for Economic Co-operation and Development (an international NGO)

DESCRIPTION: The OECD Learning Framework 2030 defines a vision and underlying principles for the future of educational systems. This framework is a work in progress and being developed through an iterative co-creation and a co-development process involving many stakeholders. The vision is to help every learner develop as a whole person, able to fulfill his or her potential and participate in the well-being of the planet. Principles include the need for:

- New solutions in a rapidly changing world w/environmental, economic, social challenges
- Broader education goals for individual and collective well-being
- Learner agency—responsibility for one’s own education throughout life
- Broad set of knowledge, skills, attitudes, and values in action
- Competencies, including being innovative, responsible, and aware
- Design principles for eco-systemic change

Development of the Learning Framework is divided into two phases. Phase I began in 2015 and finished in 2018. Two goals were accomplished: co-creating a conceptual framework with all stakeholders and conducting an International Curriculum Analysis. Phase II began in 2019 to build common ground on the principles and instructional designs that can effectively implement intended curricula and to explore the types of competencies and teacher profiles needed to meet desired outcomes.^{vi}

Appendix B - Recommendation 2: Prepare personnel for information overload

Information overload poses a serious problem for individuals, who can readily become overwhelmed by the sheer amount and velocity of information. Learners need new supports that help them filter out “noise” and meaningfully integrate the relevant “signals.” The challenge for learning professionals is to help learners navigate through information overload and to develop the internal cognitive, social, and emotional capabilities needed to self-regulate against it.

4C/ID Model

SOURCE: Van Merriënboer, J. J., & Kirschner, P. A (2017). Ten Steps to Complex Learning ^{vii}

DESCRIPTION: The 4C/ID model prescribes a process of instructional design for complex learning that incorporates cognitive load theory (CLT). CLT was designed to provide guidelines for encouraging learner activities that optimize human performance.^{viii} There are four components and ten steps:

1. **Learning Tasks:** provide a variety of authentic, whole-task experiences organized in easy to difficult tasks using faded scaffolding
 - 1.1. Design Learning Tasks
 - 1.2. Sequence Task Classes
 - 1.3. Set Performance Objectives
2. **Supportive information:** supports learning and performance of non-recurring aspects of the learning task, using cognitive strategies to help learners approach problems and providing information about how the domain is organized (mental models)
 - 2.1. Design supportive information
 - 2.2. Analyze cognitive strategies
 - 2.3. Analyze mental models
3. **Procedural information:** Prerequisite to recurrent parts of learning tasks or practice items providing just-in-time step-by-step instructions that fade away when learners acquire the expertise.
 - 3.1. Design procedural information
 - 3.2. Analyze cognitive rules
 - 3.3. Analyze prerequisite knowledge
4. **Part-task practice:**
 - 4.1. Design part-task practice

Merrill's First Principles of Instruction

SOURCE: Merrill, M. D. (2002). First principles of instruction.^{ix}

DESCRIPTION: Merrill's First Principles of Instruction model is drawn from a review of instructional theories and models. It synthesizes design principles upon which these theories and models agree, including design methods for reducing cognitive load. These five principles are:

- Problem Centered – Engage learners in solving real-world problems
- Activation – Activate learners' relevant previous experience
- Demonstration – Demonstrate what is to be learned (don't merely talk about it)
- Application – Have learners use their new knowledge or skill to solve problems
- Integration – Encourage learners to transfer new learning into their everyday lives

Mayer's 12 Principles of Multimedia Learning

SOURCE: Richard Mayer, Distinguished Professor, Psychological and Brain Sciences, University of California Santa Barbara

DESCRIPTION: Animations increase procedural-motor skills by up to 62% and problem solving up to 16%. Integrating text and pictures improves creative solutions and skill transfer by up to 50%. The 12 principles are:

- COHERENCE - eliminate extraneous information
- SIGNALING - highlight essential information
- REDUNDANCY - use graphics and narration (not on-screen text)
- PRE-TRAINING - start lessons with a quick refresher and an overview
- MODALITY - use graphics and narration versus animations and text
- MULTIMEDIA - words + pictures are better than words alone
- PERSONALIZATION - use a conversational style, not a formal one
- VOICE - narrate in a friendly human (not machine) voice
- IMAGE - the narrator's image isn't needed on-screen
- SPATIAL CONTIGUITY - put words and related pictures near each other
- TEMPORAL CONTIGUITY - show words and related pictures simultaneously
- SEGMENTING - present lessons in under-paced segments

Appendix C - Recommendation 3: Teach and support self-regulated learning skills

Targeting and supporting self-regulation skills throughout personalized learning trajectories will aid learners of all ages and promote enhanced learning efficiency across lifetimes. Key recommendations include using formative assessments to personalize support for self-regulated learning skills and mindsets; building confidence, self-efficacy, and internal “locus of control” about learning; develop goal-setting and planning skills; activating prior knowledge to enrich self-regulated learning strategy use; support metacognitive, or self-reflection, skills; and fostering habits of post-learning reflection.

Self-Regulated Learning (SRL) Assessment Instruments

SOURCE: Yarnall, L., Freed, M., & Malone, N. (2019). Self-Regulated Learning.

DESCRIPTION: Although research shows the benefits of supporting learners’ self-regulation, these interventions often rely upon the discretion and knowledge of their educators. Hence, better supporting self-regulated learning depends, in part, on enhancing the skills of teachers, workforce trainers, and managers, in addition to learners, themselves. Such a framework could be embedded into online tools and used by teachers, trainers, and learners in both classroom and workplace settings.

- **Self-report instruments:** formative assessments that can be used to personalize support for self-regulated learning skills and mindsets. Technology can deliver self-report assessments and the results can be shared with teachers and trainers or fed into adaptive learning algorithms to provide more personalized support to learners. Such assessments may target key elements known to support self-regulated learning, including: level of motivation, skills of goal setting, time management, help-seeking, preparing the study environment for focused work, and self-evaluation.
- **Structured Interview Protocols:** Drawing from questions in existing research interview protocols, technology can be adapted to deliver helpful queries to teachers and trainers. Factors useful for reflection include assessing learners’ skills for organizing and transforming information, setting goals and planning to learn, seeking information, keeping records and monitoring learning progress, preparing their study environment for learning activities, engaging in self-evaluation, meting out self-consequences, reviewing texts and notes, help-seeking, and rehearsing and memorizing.
- **SRL Processes as Events:** Education technology researchers working primarily in learning management systems are already moving towards designing more complex, process-oriented measures that can determine individuals’ deployment of self-regulated learning strategies over time. Measurement methods include think-aloud protocols and

technologies that detect errors in tasks or employ online trace methodologies (e.g., of mood and task steps) that measure individuals as they go about their learning activities (González-Torres & Torrano, 2008).^x

Pervasive Learning System (PERLS)

SOURCE: Yarnall, L., Freed, M., & Malone, N. (2019). Self-Regulated Learning.

DESCRIPTION: By providing fast access to short-form learning materials (“microcontent”), mobile applications can make it easy to use brief windows of available time for learning. Such applications use AI to identify high-interest topics, select learning activities most likely to benefit the learner, and then recommend microcontent on selected topics and activities. PERLS, a mobile app developed with DoD support, presents recommendations in the form of electronic cards that users flip through to find preferred content. The app has been evaluated with several DoD organizations, including the ADL Initiative, USNORTHCOM, and Joint Knowledge Online (JKO) to augment training in areas such as Defense Support for Civilian Authorities (DSCA). Early results show that users allowed to spend as much or little time as they wish using PERLS reported heightened enjoyment and motivation to learn and performed as well as others required to take a full formal refresher course. This app was built on a dynamic model of self-regulated learning.

Appendix D - Recommendation 4: Recognize and better facilitate informal learning such as social learning

Formal learning is a story written by an organization and addressed to its people, while social learning is a story largely written by the learners, themselves. It is often untidy, diverse, and deeply personal, as people bring their own perspectives and experiences into the learning space. When managed effectively, organizations can integrate both formal (system, process, hierarchy, and control) and social (creativity, subversion, innovation, amplification) mechanisms. More than just enhancing learning, however, the best of these programs creates organizational resilience and adaptability, reducing the risks of stagnation and operational surprise that often impede effectiveness in hierarchical bureaucratic organizations.

Lean In Circles

SOURCE: leanin.org

DESCRIPTION: Lean In Circles is an online virtual forum where individuals come together to learn from each other and achieve their goals. There are now more than 41,000 Lean In Circles in over 170 countries, and new Circles are starting every day. Circles bring together women from all walks of life, from Latina immigrants to women in the U.S. military to so-called “leftover” women in China. In these small groups, women get and give peer mentorship, sharpen their skills, and have a place to be unapologetically ambitious.

Projects That Work – School-based Service Learning

SOURCE: Edward Metz, Ph.D. Projects that Work; Research Scientist

DESCRIPTION: Impact: 90% of students were highly engaged. Projects That Work is a national research study of school-based service learning with the goal to provide teachers data-driven information to make decisions to use service learning flexibly, efficiently, and effectively. The premise is that if schools and teachers have continuously updated lists of projects that were highly rated by 20 or 25 previous classes around the country, these projects would (a) be known to the teacher and (b) could be replicated, providing all students the opportunity to realize the potential of what service learning has to offer. Preliminary findings revealed that about 90% students were highly engaged by service learning and produced positive results from many types of service learning projects. Many of the findings so far echo prior research demonstrating the role of well-designed programs that include specific activities to prepare students with a clear and compelling rationale for the project and with specific roles and responsibilities. The key to replication in schools with less expertise in service learning is likely related to the capacity for implementing strong programs.

Virtual Student Federal Service

SOURCE: www.state.gov/vsfs/index.htm

SOURCE: Bridget Roddy, Department of State

DESCRIPTION: The Virtual Student Federal Service (VSFS), originally known as the Virtual Student Foreign Service, started as a virtual internship program for U.S. college students. At its inception, students could apply to work on specific projects with U.S. diplomats posted overseas. Eventually, the organization expanded to over 30 agencies. Currently have 1200 virtual interns working on 530 projects. Students are gaining experiences and are opening their minds to ideas like applying for a Fulbright scholarship or pursuing a career with the federal government. To date, over 6000 students have participated in VSFS over the past nine years and every year it keeps growing.

GSA Open Opportunities

SOURCE: openopps.usajobs.gov

DESCRIPTION: Open Opportunities is a crowdsourcing project one-off platform for the entire U.S. Government. It is completely free, and you can connect with others with similar interests, skills, or goals. It is a non-compensated gig for your personal brand and you get recognition across gov. It is validating expertise across the public sector.

Military Families Learning Network

SOURCE: militaryfamilieslearningnetwork.org

DESCRIPTION: The Military Families Learning Network (MFLN) engages military family service providers and Cooperative Extension educators in the exchange of experiences and research to enhance the professional impact and encourage professional growth. They encourage the formation and expansion of a skilled and collaborative network of professionals who support significant positive outcomes for military service members and their families. The MFLN combines innovative online professional development, social learning and sharing, and the human and experiential resources of the Cooperative Extension system. Teams of faculty and staff from several universities work collaboratively to encourage issue-driven, learner-centered, collaborative programming. Teams connect on social media within several concentration areas: Community Capacity Building, Family Development, Family Transitions, Military Caregiving, Network Literacy, Nutrition and Wellness, Personal Finance.

Appendix E - Recommendation 5: Make assessments learner centered, developmental, and integrated

Meaningful and useful assessments should have three key characteristics. They should provide serviceable feedback, utilize evidence-based systems, and promote learner autonomy.

MInD (Marine Instructor Development) Model

SOURCE: Cognitive Performance Group (CPG) <https://cognitiveperformancegroup.com>

DESCRIPTION: CPG developed an Instructor Mastery Model describing what Marine instructors do and how they perform at five different levels of proficiency. It is guided by the research literature on cognitive skill acquisition, expertise, and instructor competencies and customized to Marine Corps instructors through knowledge elicitation with over 100 Marine and other Service subject-matter experts. Ten instructor Key Performance Areas, or competencies, are presented in the model, as well as performance indicators describing the nature of an individual's performance at each of the five stages of development. CPG is in the process of developing a set of Instructor Assessment Tools to assess an individual's current stage of learning and support the formal schools in their continuous instructor development efforts. The Mastery Model (1) prescribes instructional interventions and techniques for both instructor-led and self-directed skill improvement throughout the lifecycle of the Marine Corps instructor, and (2) guides the creation of assessment tools that measure trends in instructor capabilities as formal training system and self-development improvements are implemented. of an individual's performance at each of the five stages of development.

Earthquake-Rebuild (E-Rebuild): Online Simulation Game using Stealth Assessment

SOURCE: Shute, V., Ke, F., and Wang, L. (2017). Assessment and adaptation in games.^{xi}

DESCRIPTION: E-Rebuild is an online simulation game that explores mathematics learning through architectural tasks. Connecting mathematics to real world contexts and problems, the game platform gives students opportunities to complete building and construction tasks using mathematics and problem-solving skills. Developed using Unity 3D, the learner has two modes of play: third-person construction mode (where they perform actions such as cut, scale, rotate, and stack up) and first-person adventure mode (to navigate the virtual world, collect or trade items, etc.).

A key feature of the game is using stealth-assessment to understand and facilitate students' mathematics learning. A specialized form of evidence-centered design (ECD), stealth assessment is embedded into the learning environment to unobtrusively gather and analyze performance while learners are playing the game. One clear benefit is freeing students from

test anxiety and thus improving the reliability and validity of the assessment. Another is that feedback can be given in a timely manner to support competencies as they are being assessed.

The game developers used four interacting and interdependent design steps for interweaving game and assessment elements in E-Rebuild:

1. Develop competency models and selecting game mechanics to allow players to perform each competency;
2. Design game task templates and contextual scenarios along with the Q-matrix;
3. Design the game log file based on the Q-matrix, and;
4. Design in-game support as both live input for data-driven assessment and adaptive feedback.

Authentic Assessment Toolbox

SOURCE: <http://jfmueeller.faculty.noctrl.edu/toolbox/index.htm>

DESCRIPTION: The Authentic Assessment Toolbox is a resource that explains in detail and provides examples for measuring and improving student learning using authentic assessments. Although it is meant for K-12 teachers, it transcends this mission by providing a resource that any teacher or designer of instruction can use.

Jon Mueller, the author, defines authentic assessment as one in which students are asked to demonstrate their essential knowledge and skills by performing a real-world task. There are four steps involved in the process of creating authentic assessments:

1. Identifying standards
2. Selecting authentic tasks
3. Identifying the criteria for the task
4. Creating the rubric

The toolkit provides comprehensive explanations and examples (grouped by school level: elementary, middle/junior high, high school, and college/university) for each step, including workshops for writing a good standard, creating an authentic task, and creating a good rubric. There is also an explanation of how to use portfolios as methods for students to reflect on the process and development of related skills during their learning.

Intelligent Tutoring Authoring and Delivery System (ITADS)

SOURCE: <https://www.stottlerhenke.com/solutions/education-and-training/itads/>

DESCRIPTION: ITADS is a simulation-based intelligent tutoring system (ITS) for enlisted Information Systems Technician (IT) Sailors. It was used as a proof-of-concept that demonstrated the value of ITS based learning systems to train systems administrators to manage their increasingly complex computer networks. The trainer provides authentic hands-on practice in real-world troubleshooting and maintenance situations via virtualized shipboard networks within a simulation. ITADS uses stealth-assessment – data collected and logged while players are immersed in their IT training activities – to provide guidance and insight into what they have learned up to that point and to inform its future interventions.

A summative training effectiveness evaluation showed higher completion rates for the experimental (63%) compared to the control group (38%).^{xii}

Appendix F - Recommendation 6: Use personalization and mastery learning to optimize outcomes

Generally, personalized learning improves learners' show recall and near- and far-transfer. It can engender deeper understanding as well as hone higher-order cognitive skills, such as leadership and adaptive thinking. Personalization is often best when combined with mastery learning, such as focusing on holding consistent performance standards and allowing the developmental trajectories (e.g., time, learning approach) to vary.

Predictive Performance Optimization

SOURCE: Air Force Research Lab

DESCRIPTION: The Air Force Research Lab developed the Predictive Performance Optimization (PPO) algorithms to predict when someone would need refresher training. It uses quantitative models of human learning and forgetting to optimize and personalize training schedules. For instance, the Air Force conducted a trial with medical personnel, training them on CPR procedures with medical mannequins. Depending upon their learning speed and overall performance, the algorithm was able to predict when each student would need to complete refresher training. This ensured the less capable students were retrained before their abilities perished, and it allowed the more experienced students to avoid unnecessary required compliance training. Use of PPO will allow a shift from calendar-based training to cognitively principled personalization schedules, which minimizes training costs and time while maximizing performance effectiveness.

Seven Principles for Smart Teaching

SOURCE: *How Learning Works*, Ambrose et al.

DESCRIPTION:

1. **Learners' prior knowledge can help or hinder learning:** Teachers should talk with other instructors and use diagnostic tests of prior knowledge to learn about their students. Be explicit to students about the connection between new material and their prior knowledge; this aids in long-term retention.
2. **How individuals organize knowledge influences how they learn It also affect how they apply what they know:** Make use of techniques that make knowledge organization schemes explicit, such as concept maps. Look for patterns of mistakes and misconceptions in learners' conceptions.
3. **Learners' motivation determines, directs, and sustains learning:** Help learners see the value in what is being taught and how it helps their future development. Provide

authentic tasks with an appropriate level of challenge (simulations and games are useful). Get learners to understand the reasons for success and failure.

4. **Learners must acquire and integrate component skills:** To develop mastery, learners must need to practice integrating component skills and know when to apply what they've learned. Be aware of expert "blind spots"—steps they perform unconsciously and are not well-articulated in instruction. Provide isolated practice of component skills in diverse contexts and then facilitate the integration of component skills in more challenging tasks.
5. **Goal-directed practice with targeted feedback enhances learning:** Phrase instructional goals in terms of capabilities rather than knowledge. Provide time for deliberate practice, and pair this with feedback that focuses on specific items that need improvement.
6. **The social, emotional, and intellectual context impacts learning:** Learner current development is influenced by the context, and a positive and constructive tone of communications within the learning community often improves learners' motivation and behavior.
7. **Students must learn to monitor and adjust their own learning:** Help learners develop metacognitive skills, such as self-monitoring. A malleable, rather than fixed, perspective of intelligence can also be promoted and has been found to influence performance.

Government Personalized Blended Learning (CLD)

SOURCE: Dr. Suzanne Logan - SES Federal Executive Institute (Mallon, 2010)

DESCRIPTION: Programs with strong learning cultures improved in innovation (46%), productivity (37%), Quality (26%), Skills for the future (58%).

Leadership for a Democratic Society supports individuals at the GS15 and SES levels. It is designed to cover four weeks in-residence; twice a year it is two weeks in-residence with six months of online work. The benefit of the in-residence program is that learners can leave their daily work duties to focus on the learning experience and build and expand networks. The first week is extremely intense and they are not allowed to leave the first two weeks. Learners are put in groups of six to nine people. By the end of that week, groups are able to use tools to honestly assess how the group works and the individual strengths and improvements.

Learning on Demand at the Point-of-Need

SOURCE: Mike Smith, ICF contractor for the Federal Aviation Administration (FAA)

DESCRIPTION: Isolating interacting information reduces instruction time 62%. The FAA discovered through study that the lines between training and operations are blurring. For example, Maintenance, Repair, and Overhaul (MRO) is one of the largest facilities for maintenance. Aircraft information is sent to a routing central cell that then loads the information onto a mobile “learning on-demand at the point-of-need” system, a sensing system that translates straight into an operational track. Aircrafts have sensors with analytics to make profiles and tell pilots when corrective action is necessary, especially for safety issues. Even though, the FAA has the ability to provide information back to pilots, their union was assigned to broker the data and training experiences and information. This put a series of approvals between the data and the stakeholder to protect the individual pilot rights. But that also weakened the expediency of exchanging information and focusing on timely learning experiences.

Adaptive Learning at ASU

SOURCE: Dr. Kurt VanLehn – Arizona State University

DESCRIPTION: About five year ago at Arizona State University, an adaptive general education structure with approximately 13 modules for the course was created. Modules are linear, but the units within the module are not; students can go through the path of their choice but are led to complete all of them.

ALEX, a program used both for adaptive placement and instruction. But did not always meet the need of the students. They might be placed in a module that is too easy or too hard and still be required to attend the class, even if it was self-paced. Students are supported by an assigned teaching assistant. Two of the three undergraduate assistant visits are problem solving experiences. The undergraduate walks around and helps students while the instructor supervises the class and the exams. Each week, they also structure small group work where the instructor hands out more difficult problems to cultivate group problem solving skills. Over time, undergraduate assistants act like mentors by finding the failing students and assisting in college adjustment issues. Students also have accessed a web-based system to connect with the counseling staff to and there are methods for counselor to proactively help first-time freshman.

Appendix G - Recommendation 7: Employ system-wide strategies for long-term, big-picture effectiveness

Advances in learning science, technology, data science, organizational dynamics, and public policy. *Interoperability* allows data to easily flow among applications that are developed for different purposes using a standardized vocabulary, structure, and cadence. Interoperability specifications form the fundamental building blocks for lifelong learning by establishing consistent protocols that can be universally understood and adopted by any component of the learning ecosystem to enable data exchange about learners, activities, and experiences.

CHUNK Program

SOURCE: Michelle Isenhour, Assistant Professor, Naval Postgraduate School

DESCRIPTION: Curated Heuristic Using a Network of Knowledge (CHUNK) connects individuals to courses in individualized ways. CHUNK Learning provides a curated way of moving through a network of modules composed of educational material joined together by common attributes (i.e., tagged with competency or skill levels). A network science approach is used to develop an initial software prototype, which recommends learning content to students based on their current interests. The goal is to relate it to the learner's background to ensure that it relates to his or her work.

Government Talent Management

SOURCE: Mr. Doug Tharp, Nuclear Regulatory Commission (Yoon, et al., 2008)

DESCRIPTION: Student achievement increases by 21% when teachers receive professional development. When the Nuclear Regulatory Commission acquired a new talent management system to replace the success factors system, they also obtained a learning record store (LRS). This allowed them to focus on a task-based competency model with observable behaviors at five levels. For assessment, they are using a software observation (70-10-10 method). The learner can create their own approach through informal learning methods. From the LRS, the system automatically develops an individual development plan and that data can be used to help you talk to connect with the supervisor or the learner can assess their skills against other jobs. The data can help to identify a shift in workload or pair the learner with the best fit or job for them. In the future, the data can identify people from a database to fill those roles.

Talent Pipeline Management (TPM)

SOURCE: Credential Engine

DESCRIPTION: At higher education institutions, 96% of Chief Academic Officers believe they are effectively preparing students for work. Among business leaders, 11% strongly agree. This disparity highlights a disconnect between what businesses want new employees to know before they show up for work and what the applicant pool actually knows. TPM uses supply chain principles to call on business and public policy leaders to transform education and workforce systems to be employer-led and demand-driven. The TPM Academy trains state and local leaders, business associations, employers, and economic development agencies to drive partnerships with their education and training providers based on need.

Job-Data Exchange

SOURCE: Credential Engine

DESCRIPTION: The Job Data Exchange (JDX) is a set of open data resources, algorithms, and reference applications for employers and their HR technology partners to use in improving how employers communicate competency and credentialing requirements for in-demand jobs. Today, 50% of open, available positions in this country go unfilled, because employers cannot find the right talent for their critical positions. At the same time, education, training, and credentialing providers need better, faster, clearer signaling from employers on what skills are most in demand in a changing economy.

The JDX is the same as the Job Registry Project, which was the name used to reference the idea behind the project's design. The JDX is different than job boards, which aggregates and displays jobs posted by employers for the purposes of connecting to available job seekers. The JDX will be a resource for employers and their HR technology partners to more clearly define competency and credential requirements for jobs distributed to talent sourcing partners, such as job boards and preferred education, training, and credentialing partners. It will improve the data that human resource applications, like job boards, rely on to deliver services. The JDX will be developed and pilot tested with participating employers and their human resource technology partners.^{xiii}

Appendix H - Recommendation 8: Integrate with the wider social/technical/organizational system

New learning science methods should be integrated with other, interdependent parts of the larger system such as technological and human infrastructures, learning design, governance, policy, and commitment.

The 60 Year Curriculum

SOURCE: Harvard University (Christopher Dede, Ed.D.)

DESCRIPTION: Hunt Lambert, Dean of Harvard's Division of Continuing Education (DCE), is leading the 60 Year Curriculum (60YC) initiative to transform lifelong learning. The 60YC initiative is focused on developing new educational models that enable each person to re-skill as their occupational and personal context shifts. Given this rate of change, the 60YC focuses on long-term capacity building—enhancing students' interpersonal and intrapersonal skills for a lifetime of flexible adaptation and creative innovation—as well as short-term preparation so that they are college- or career-ready. The 60YC also advances two other goals beyond preparation for work to prepare students to a) think deeply in an informed way and b) be thoughtful citizens and decent human beings. Finally, the 60YC initiative considers the organizational and societal mechanisms by which people can re-skill later in their lives, when they do not have the time or resources for a full-time academic experience that results in a degree or certificate.

Harvard's approach is to reinvent unemployment insurance as “employability insurance,” funding and delivering this through mechanisms parallel to health insurance.

According to Chris Dede, the biggest barriers the 60YC faces involves *unlearning*: “We have to let go of deeply held, emotionally valued identities in service of transformational change to a different, more effective set of behaviors. I hope higher education will increase its focus on the aspirational vision of 60YC as an important step towards providing a pathway to a secure and satisfying future for our students.”^{xiv}

T3 Innovation Network

SOURCE: U.S. Chamber of Commerce Foundation and Lumina Foundation

DESCRIPTION: In early 2018, the U.S. Chamber of Commerce Foundation and Lumina Foundation launched the T3 Innovation Network to bring businesses, postsecondary institutions, technical standards organizations, and human resource professionals and their technology vendors together to explore emerging Web 3.0 technologies in an increasingly open and decentralized public-private data ecosystem. The Network has since grown from a kickoff meeting of 60 individuals to a thriving network of over 128 organizations. In its first six months of existence, the T3 Innovation Network held ten webinars, produced a background paper, four work group reports, and identified 50 use cases resulting in two dozen potential pilot projects. A space for key stakeholders to coordinate is needed to ensure that an equitable and ethical data ecosystem emerges that creates shared value and opportunity among all stakeholders in ways that advance opportunities for learners and the American worker. The T3 Network has become the go-to space to explore new and emerging technologies—such as Semantic Web, AI, machine learning, and distributed ledger technologies— and to advance recommendations for an open, shared data infrastructure for learners and workers alike.

SAMR Model of conversion to online teaching

SOURCE: Puertedura, R. R. (2006, November 28).^{xv}

DESCRIPTION: The SAMR model highlights our tendency to use new technologies in old-school ways. It consists of four classifications of technology use for learning activities:

- **Substitution:** The technology provides a substitute for other learning activities without functional change.
- **Augmentation:** The technology provides a substitute for other learning activities but with functional improvements.
- **Modification:** The technology allows the learning activity to be redesigned.
- **Redefinition:** The technology allows for the creation of tasks that could not have been done without the use of the technology.

Appendix I - Case Study: Sailor 2025: Ready Relevant Learning

SOURCE: Vision and Guidance for Ready Relevant Learning, Commander, U.S. Fleet Forces Command^{xvi}

Sailor 2025 is the Navy's program to improve and modernize personnel management and training systems to more effectively recruit, develop, manage, reward, and retain the force of tomorrow. While the Navy is in a good position today with respect to recruiting, retention, and manning, it must adjust how business is conducted for the sailors of the future. Recruiting, developing and retaining the right number of Sailors with the right skills to man the force demands innovation built on a framework of three pillars: Personnel System Modernization, Ready Relevant Learning (RRL), and Career Readiness.

Based on a recent analysis at Navy Personnel Command (NPC), the Navy brings in approximately 40,000 people in any given year, and 30,000 or so are in training at any given time, out of a total force of about 326,000. Therefore, peak operating efficiency of the fleet, based on manpower gaps due to training requirements alone, is only about 90%, and about 75% of the newest Sailors are away from their units for training and not contributing in any way to their mission readiness.

In addition, NPC analysis has shown that the Navy annually absorbs approximately 4,000 man-years of loss, largely due to congestion and delays in our training pipelines. Standard planning factors would put the financial impact of these losses at well over \$400 million per year.

RRL is a holistic approach to reimagining how the Navy trains its Sailors, representing a significant change from the ways Sailors have been trained in the past. Specifically, RRL will change:

- (1) when to provide training,
- (2) how training is delivered, and;
- (3) how to keep training relevant to the real-world needs.

These changes require sustained focus across three lines of effort: career-long learning continuum, modern delivery at point of need, and integrated content development.

RRL Stage 1: Block Learning

The first stage of the transition is a shift to what is called Block Learning. In this stage, current accession-level training is analyzed to link all learning objectives as tightly as possible to the real-world points of need in a Sailor's career, including rating reviews and content re-alignment.

RATING REVIEW ANALYSIS

This activity entails the detailed analysis of learning objectives and content to align current training as closely as possible with the real-world work requirements of Sailors in the fleet. All current training is analyzed by relevant fleet experts as well as learning science experts to

identify which content should be preserved in the accession pipeline, and which content should be moved to a more appropriate time in the Sailor's career to minimize the atrophy of knowledge and skills.

CONTENT RE-ALIGNMENT

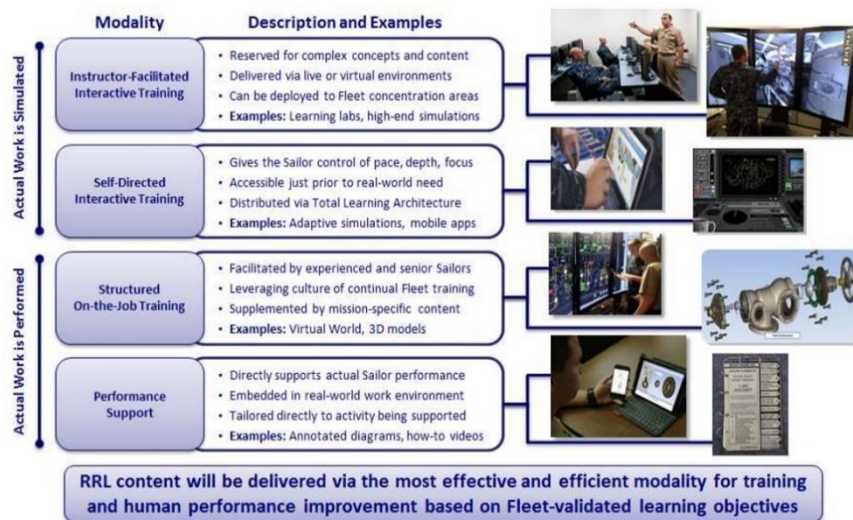
This activity entails re-aligning training content in accordance with the findings of the Rating Review Analysis. In this step, the only thing that will be changed is the timing of training. By moving training from the accession pipeline to a point during the first or second operational tours of our Sailors, we create an opportunity for Sailors to get to their units sooner with the knowledge and skills they need in their first one or two years onboard. Then, follow-on training is scheduled at a point when it will be most useful and relevant to Sailors, supporting their ongoing professional development, and preparing them for peak performance in emerging roles.

HIGH-LEVEL OPERATIONAL CONCEPT

The most significant change in this stage is that Sailors in many rating specialties will *no longer get all of their technical training before reporting to their first operational unit*. Instead, fleet subject matter experts and certified learning specialists will identify the knowledge and skills required for full performance in the first two years of service, and all Sailors will complete that training before reporting to their first operational unit. Then, Sailors will complete follow-on training to develop new knowledge and skills closer to the time of actual need based on their expanding roles and responsibilities.

Stage 2: Enhanced, Accessible Learning

In this stage, we will integrate a disaggregated system of independently-operated databases to make training more accessible at the waterfront, and we will modernize training content across the careerlong continuum of learning for every Sailor. The content-modernization process is defined as analyzing and optimizing the media types, media modes, and delivery methods of performance-centric training content and delivering it at the ideal time and in a location convenient to the Sailor, either at the waterfront or in the actual work environment. This process takes advantage of modern technologies to deliver training in the most effective way based on key principles of the science of learning.



KNOWLEDGE CAPTURE

This phase identifies the *what* of Ready Relevant Learning. Working primarily with our schoolhouses, Learning Centers, and Systems Commands, analysts will examine current course content, as captured in classroom presentations, models, whiteboard drawings, demonstrations, videos, labs, assignments, instructors' elaborations and explanations, and published training objectives and course guides, as well as technical manuals, personnel qualification standards, and occupational standards.

DOMAIN ANALYSIS

This phase identifies the *when* of Ready Relevant Learning. In other words, this phase includes Fleet subject matter experts and certified instructors in the process of conducting detailed analyses to *identify when it would be most appropriate to train specific knowledge and skills* based on a close examination of the real-world performance requirements of our Sailors.

Recommendation: Curate supporting interoperability structures

- 1. Identify and describe organizational competencies:** Organizations need to inventory the skills required to successfully perform all business functions within their institutions. A competency framework provides the common reference model across HR, training, and education systems, and the critical indicators associated with competencies within it help quantify individuals' performance.
- 2. Formulate a data strategy:** A cohesive data strategy needs to be implemented to help identify all of the relevant data types required to support the human capital supply chain, to define the relevance of different data types over time, to identify an approach for capturing the decay of importance between different data types, and to identify authoritative sources for generating each data type. An effective data labeling strategy will enable automation, increased analytics, and an associated lifecycle for how long the different data elements remain relevant. Data labeling attaches meaning to the different types of data, correlated to the different systems that generate the data across the lifelong learning continuum.
- 3. Define standards, specifications and shared vocabularies:** There are benefits to designing systems that use shared vocabularies to describe learning activities, digital content, learners, and competencies. Activity tracking across learning activities work best when each activity uses a common library of terms for different instructional modalities, media types, or as a roll-up to other systems in the organization (e.g., talent management).
- 4. Define the governance strategy:** Organizations need to be responsive and proactive in recruiting, educating, and preparing their existing workforce for the future. Workforce planning strategies should tie into the lifecycle management of these critical components. Governance should also be addressed in the data strategy so that specific indicators and outcomes can be tracked, measured, and analyzed.

MEDIA ANALYSIS

This phase identifies the *how* of Ready Relevant Learning. Based on initial findings from the domain analysis, analysts will examine available and emerging instructional media technologies (e.g., game-engine based simulations, adaptive/intelligent instructional content, and mobile platforms) to select the most appropriate delivery method for each learning objective to optimize training effectiveness, based on science of learning insights as well as environmental and cost constraints.

Recommendation: Use SAMR Model of conversion to online teaching to ensure information is gathered and translated effectively

The SAMR model highlights our tendency to use new technologies in old-school ways.

- SUBSTITUTION Technology acts as direct substitute, with no functional improvement
- AUGMENTATION Technology acts as direct substitute, with functional improvement
- MODIFICATION Technology enables significant task redesign
- REDEFINITION Technology enables new tasks, previously inconceivable

CHUNK Program

“CHUNK connects individuals to courses in individualized ways. The goal is to relate it to your background to ensure that it relates to your work and imbeds in long term memory. The CHUNK map shows the connections between the pieces to help understand the prerequisite hierarchy. Red is what I’m enrolled in and black is what are accessible to me but I’m not doing and not required. Blue I’ve completed. Large is the curriculum and the courses are the smaller pieces. Then smallest ones are the chunks. Data is currently everywhere and connecting to the learning management system. If you keep your data elsewhere then you can’t always hyperlink to it if the internet is out. It has a basic GUI for editing (adding activities) – just basics – name, add picture, keywords (tagging), material, (could add competencies). There’s also a support tool in the upper right. For example, you can Ask an Expert – a subject matter expert (SME) is available for tutoring. You can also jump to the assessment if you’re directed to this chunk; you can take it without doing the learning if you already know it.”

- Michelle Isenhour, Assistant Professor, Naval Postgraduate School

FAA STRATEGY SELECTION

Four broad categories of human performance and training solutions will be used to drive selection of the most effective and efficient approach for a given learning need: Instructor-Facilitated Interactive Training (IFIT), Self-Directed Interactive Training (SDIT), Performance Support (PS), and Structured On-the-Job Training (SOJT). These broad categories allow RRL to use Navy and industry best-practices while providing innovative development and deployment of training content. As new technologies are proven and become available, they will be placed in one of the four categories and sub-processes will be refined to include them as potential options for future training solutions. Multiple strategies may be combined as a training solution.

Recommendation: Seven principles for smart teaching

- (1) Teachers should talk with other instructors and use diagnostic tests of prior knowledge to learn about their students.
 - (2) Make use of techniques that make knowledge organization schemes explicit, such as concept maps. Look for patterns of mistakes and misconceptions in learners' conceptions.
 - (3) Provide authentic tasks with an appropriate level of challenge (simulations and games are useful). Get learners to understand the reasons for success and failure.
 - (4) Provide isolated practice of component skills in diverse contexts and then facilitate the integration of component skills in more challenging tasks.
 - (5) Goal-directed practice with targeted feedback enhances learning. Phrase instructional goals in terms of capabilities rather than knowledge.
 - (6) The social, emotional, and intellectual context impacts learning. Learner current development is influenced by the context, and a positive and constructive tone of communications within the learning community often improves learners' motivation and behavior.
 - (7) Help learners develop metacognitive skills, such as self-monitoring. A malleable, rather than fixed, perspective of intelligence can also be promoted and has been found to influence performance.
-

“What we found when we studied the FAA is that the lines between training and operations are blurring. Pilots can’t be punitively damaged by data findings—but can be informed.”

- Mike Smith, ICF contractor for the Federal Aviation Administration (FAA)

Recommendation: Make Assessments learner-centered and motivating

- (1) **Plan for curricular alignment early on:** Good assessment is planned for very early in the instructional design process, and it begins by imagining what post-instructional success looks like. Outcomes and assessments are like the “bones” of instruction and should be constructed first, so that lessons may be structured around them.
 - (2) **Integrate feedback into learning design:** As with assessment, feedback approaches should be incorporated early into the instructional design process. While feedback as a dialogue between instructors and learners is highly productive, learners can (and often do) obtain feedback from multiple sources. How these multidirectional and distributed feedback loops fit into the design of instruction requires planning.
 - (3) **Plan for Systemic Change:** Organizationally, there should be a forcing function or mechanism that causes the results of assessments to be utilized. However, teachers and trainers, or automated systems, shouldn't make those decisions alone. Acting in response to assessment needs is important, but equally critical is considering how to bring learners into that equation.
-

CONTENT CONVERSION

This is the phase in which new RRL content is actually created. This includes the design, development, and delivery of the modernized content that will be delivered to Sailors over the course of their career-long learning continuum. A wide variety of modalities and methods will be used to design approaches to training and human performance improvement that can be delivered in the right place, at the right time, via the most effective means for our Sailors.

Recommendation: Utilize assessment to make personalized recommendations for when to teach specific knowledge or skills

- (1) **Cultivate learner motivation:** *Boredom reduces learning up to 25%* - When designed and implemented well, assessments afford rich opportunities to develop learners' concepts, communication skills, subject-area expertise, judgements, and abilities.
 - (2) **Make assessment and feedback learner-centered:** Learners aren't merely passive vessels but active participants who seek out useful feedback when motivated to do so. Success in assessment is tied to learner engagement.
 - (3) **Learning on Demand at the point-of-need:** Isolating interacting information reduces instruction time 62%.
 - (4) **Interweave assessments through instruction:** Instruction and assessment have a truly symbiotic relationship; they're inextricably linked and interactive.
 - (5) **Vary the types of data collected:** A functional system of assessment for learning should be eclectic and incorporate a variety of measures such as quantitative, qualitative, estimated, and predictive data types.
 - (6) **Mitigate the fluency illusion:** Learners require opportunities for practice assessments such as pre-tests or trial performances that are spaced out in time, occur in a mix of locations or under varying conditions, and are sequenced in a special way that mixes problems or content elements.
-

Assessment Variation

Right now, people do assessments but the value of doing them on line compared to paper is higher because there's too much opportunity for error when hand-keying; we try to use connectivity because delivering online limits the human errors. And if you have a locked down browser and it's proctored, you've got different questions, more secure and more valid, more defensibility assessments. When you can meta-tag items, you can assess difficulty with different questions and prove it, validate it - allowing everything to be valid, fair, and reliable – and it's defensible.

-Stacy Poll, Questionmark

HIGH-LEVEL OPERATIONAL CONCEPT

The most significant change in this stage of evolution is that modernized training content will be available at the waterfront, so that Sailors will no longer need to travel to rating-specific schoolhouses to get the training they need. Instead, they will be able to access self-directed training and performance support while pier-side, and they will be able to attend instructor-facilitated training at nearby training centers. Instead of Sailors needing to take time away from their units to go to training, this is the stage in which the training starts going to the Sailor.

Stage 3: Modernized, On-Demand, Fleet-Responsive Learning

This stage represents the culmination of the RRL journey. At this point in the evolution of RRL, all training content will be accessible to Sailors where and when they need it, and new training will be delivered to the Fleet much faster than current training systems and processes allow. Also, in this stage, the career-long learning continuums for Sailors will be expanded to include technical and non-technical training alike, and Sailors and their supervisors will have increased control over the timing and pace of their individual development. Finally, this is the stage in which the information architecture that enables individual training will be fundamentally transformed. Specifically, *a Navy-wide solution, called the Total Learning Architecture, will enable real-time scheduling, delivery, tracking, and assessment of training across all communities.* Through the high-bandwidth, two-way data flow enabled by this system, Sailors will be able to access the training they need when they need it, where they need it in order to meet Fleet-driven requirements.

Appendix J - Strategic Guidance: Learning

*To succeed in the emerging security environment, our Department and Joint Force will have to **out-think, out-maneuver, out-partner, and out-innovate** revisionist powers, rogue regimes, terrorists, and other threat actors. – National Defense Strategy, 2018*

As the world continues to evolve into an increasingly volatile, uncertain, complex, and ambiguous environment, it requires the development and support of cognitive agility, rapid team coordination, and the ability to constantly learn and adapt. But it is not enough to survive this chaos, military personnel must thrive in it. To accomplish this goal, they need to learn more, learn it at a higher level of cognition, and need to adapt to an ever-changing environment requiring continuously more information and the ability to assimilate it quickly in order to optimize effectiveness. However, the human mind has significant limitations, making it necessary to consider all possible complementary human-computer optimizations. In other words, we need to better understand the principles of learning science to create strategies and tactics that better enable military personnel to operate in this complex environment. To address these considerations, each military branch has elucidated these strategic goals:



Army Learning Concept;
Army Learning Concept for T&E 2020-2040; Force 2025 and Beyond

- Develop a **holistic** military learning model
- Increase **problem-focused** learning
- Improve **technology-delivered** instruction
- **Personalize** learning
- Use learning methods that engage learners to **think** and understand in context
- Define a continuous, adaptive, **career-long** continuum of learning
- Guide Army future force **employment**



Sailor 2025;
Ready, Relevant Learning

- Modernize the Personnel System; Provide **Ready, Relevant Learning**; Create an Enriched Culture
- Create a **career-long** modernized continuum of learning
- **Improve instructional quality**; blended learning; ease of access
- Leverage **cloud-hosting**



Air Force Global Science & Technology Vision;
Agile, Learner-Centered T&E

- Train across multiple mission sets (**Live, Virtual, Constructive**)
- Use **Modeling & Simulation** for agile and robust decision-making
- Establish enterprise **force development**; On-Demand and On-Command; Blended Learning; **Credentialing/Competencies**; Integrated AF **Learning Ecosystem**; and Master **Learning Record**



Marine Corps Operating Concept;
CMC Guidance 2015-18

- Leverage **technologies, partnerships, and innovation**
- Create training to equip Marines to thrive in **complex**, urban littorals
- Recognize the need of the individual Marine to think and act effectively under **chaotic, uncertain, and adverse** conditions

Appendix K - Military Innovation

Service	Laboratory	Website	Description
DoD wide	Defense Advanced Research Projects Agency (DARPA) - Information Innovation Office	https://www.darpa.mil/about-us/offices/i2o	High-potential, high-impact research to support defense-related needs
	Defense Innovation Unit Experimental (DIUX)	https://www.diux.mil/	Accelerating commercial research innovation for national defense
	Defense Digital Service	https://dds.mil/	Projects and challenges using data including hacking, coding, and analysis
	Office of Small Business Programs	https://business.defense.gov/	Oversees multiple small business innovation opportunities for defense
	MD5	https://community.md5.net/md5/landing	Innovation accelerator connecting internal projects to external thought leaders and innovators
	Defense Innovation Board	https://innovation.defense.gov/	Advisory board of national technology leaders for the Secretary of Defense
	Innovative Missions Capabilities (IMC) - NSA	https://www.nsa.gov/business/programs/programs-for-innovation/	Direct funding support to businesses and universities of any size or type that can help national security
	Defense Innovation Marketplace	https://defenseinnovationmarketplace.dtic.mil/	Connecting DoD scientists and solutions through funding, coordinated meetings, and communities of interest
	Defense Technical Information Center (DTIC)	http://www.dtic.mil/dtic/	Repository of research findings to better connect DoD scientists and solutions
	Coalition Warfare Program (CWP)	https://www.acq.osd.mil/ic/cwp.html	International joint research for defense
	Hacking for Defense (H4D)	https://www.h4d.org/about.html	Short-term collaboration challenges with universities for DoD
	Small Business Innovation Research (SBIR) Program/Small Business Technology Transfer (STTR) Program	https://business.defense.gov/programs/sbir-sttr/	Innovation grants for small businesses
	Rapid Innovation Fund	https://business.defense.gov/Programs/RIF/	Funding for small business mature technologies for transition
	Rapid Reaction Technology Office	https://www.acq.osd.mil/ecp/PROGRAMS/RRTO.html	Funding for rapid prototype building to reduce development risk
Marine Corps	Marine Corps Innovation Challenge	https://www.marines.mil/News/Messages/Message-Display/Article/671270/1st-qtr-fy-19-commandants-innovation-challenge/	Commandant's challenge for internal innovative ideas
	Rapid Capabilities Office (MCRCO)	https://www.mcwl.marines.mil/Divisions/RCO/	Supports the rapid development of disruptive technology
	MCWL - Experimentation Division	https://www.mcwl.marines.mil/Divisions/Experiment/	Multi-method innovation lab that supports strategic goals and uses operating forces for experimentation
	MCWL - Future Technology Office	https://www.mcwl.marines.mil/Divisions/Science-and-Technology/Future-Technology-Office/	Pre-screening innovative technology to support readiness and mission success

Service	Laboratory	Website	Description
	Nexlog	http://www.secnav.navy.mil/innovation/HIML_Pages/2017/06/NexLog.htm	Supports adoption of emerging technologies
Navy	The Athena Project	http://www.secnav.navy.mil/innovation/HIML_Pages/2015/05/AthenaProject7.htm	Sailor challenge program to promote "intellectual courage"
	Naval Agility	http://www.secnav.navy.mil/innovation/Pages/Hmle.aspx	Transforming from innovation to agility focusing on emerging operational capabilities and building an adaptive workforce
	Office of Naval Research (ONR)	https://www.onr.navy.mil/	Supports basic and applied research across 89 programs focused on topics ranging from maritime sensing to bio-inspired autonomous systems
	Velocity Lab	https://www.doncio.navy.mil/CHPS/ArticleDetails.aspx?ID=9723	Supports Center for Security Forces Naval Operations
	University Research Initiatives	https://www.onr.navy.mil/en/Science-Technology/Directorates/office-research-discovery-invention/Sponsored-Research/University-Research-Initiatives	Supports defense-related research within the university system to access and build basic-level investigators
	PEO EIS Innovation Cell	http://www.secnav.navy.mil/innovation/innocell/Pages/default.aspx	Innovative methodology that uses challenges to identify promising solutions and enabling groups to scale enterprise-wide
	Naval Postgraduate School - Joint Interagency Field Experimentation (JIFX)	https://my.nps.edu/web/ix	Naval Postgraduate School's program for connectivity to commercial innovators
Army	Army Mad Scientist Lab	http://madsclblog.tradoc.army.mil/	Collaboration network that attracts experts across multiple fields to imagine the art of the possible
	US Army RDECOM	https://www.army.mil/info/organization/unitsandcommandments/commandstructure/rdecom	Supports basic and applied research for Army engineering needs
	Army Rapid Capabilities Office	http://rapidcapabilitiesoffice.army.mil/	Focuses on mission critical issues to find and rapidly develop solutions
	TARDEC	https://tardec.army.mil/	Supports basic and applied research in tank automation and engineering
	Army RDECOM Research Lab	https://www.amysbir.army.mil/Default	Supports small business innovation for army needs
	Army Medical Research and Materials Command	http://mmcamedd.army.mil/	Supports basic and applied research to advance military medicine
	Rapid Equipping Force (REF)	http://www.ref.army.mil/	Using soldier-driven solutions to rapidly equip the force and close the research-practice gap
Air Force	Air Force Rapid Capabilities Office	http://www.af.mil/About-Us/Fact-Sheets/Display/Article/104513/rapid-capabilities-office/	Air Force advisory program to the Board of Directors chaired by the Undersecretary of Defense for Acquisition, Technology, and Logistics for rapid sailing of promising solutions
	AF Small Business	http://www.airforcesmallbiz.org/	Support for small business innovation answering Air Force needs

Service	Laboratory	Website	Description
	Air Force Research Laboratory	https://teamafrl.afciviliancareers.com/	Supports basic and applied research focused on air, space, and cyberspace needs
	Air Force Research Laboratory New Mexico	http://www.afrlnewmexico.com/	Leading the way in the nation's laser, optical, and space supremacy technologies
	Air Force Office of Transformational Innovation	http://www.transformaf.mil/About/What-We-Do/	Supporting ideas from junior servicemembers to distribute impact and innovation; Technology challenges to identify promising solutions; Cognitive computing; leadership roles currently vacant
	Comparative Technology Office	https://www.acq.osd.mil/ecp/programs/cto.html	Focused on emerging capabilities and prototyping for better buying power
	CyberWorx (USAFA)	https://www.usafa.edu/af-cyberworx/	Using design thinking to support advancements in cyber skills within developing airmen and outreach to the community
	Special Operations Forces Acquisition, Technology, and Logistics (SOCOM AT&L)	https://www.socom.mil/SOF-ATL	Supports basic and applied research for Special Operations Command

End Notes

ⁱ Detailed statistics for HDPs and key skills are available in the journal article: Flanagan, S., Horn, Z., Knott, C., Diedrich, F., Halverson, K., Lucia, L., & Weil, S. (2015). *Teaching social interaction skills with stealthy training techniques*. *Procedia Manufacturing*, 3, 4036-4043.

ⁱⁱ Selected publications: <http://ei.yale.edu/ruler/results/>

ⁱⁱⁱ <https://apps.dtic.mil/dtic/tr/fulltext/u2/a626642.pdf>

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^{vi} More details are available in the position paper: [http://www.oecd.org/education/2030/E2030%20Position%20Paper%20\(05.04.2018\).pdf](http://www.oecd.org/education/2030/E2030%20Position%20Paper%20(05.04.2018).pdf)

^{vii} Van Merriënboer, J. J., & Kirschner, P. A. (2017). *Ten steps to complex learning: A systematic approach to four-component instructional design*. Routledge.(third version).

^{viii} The link between CLT and instructional design is detailed in this article: Sweller, J., Van Merrienboer, J. J., & Paas, F. G. (1998). *Cognitive architecture and instructional design*. *Educational psychology review*, 10(3), 251-296. Van Merrienboer further explores the synthesis of CLT, 4C/ID and self-directed learning in this article: Van Merriënboer, J. J., & Sluijsmans, D. M. (2009). *Toward a synthesis of cognitive load theory, four-component instructional design, and self-directed learning*. *Educational Psychology Review*, 21(1), 55-66.

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^x González-Torres, M. C., & Torrano, F. (2008). *Methods and instruments for measuring self-regulated learning. Handbook of Instructional Resources and their Applications in the Classroom*, Nueva York, Nova Science, 201-219.

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