The New Wave of Training Technology Standards

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ABSTRACT

Technical standards often shape the economics of how new technologies are disseminated and applied. After Web-based instruction and computer-based simulation emerged in the late 1990's, a wave of new standards that included the Sharable Content Object Reference Model (SCORM), Distributed Interactive Simulation (DIS) and High-Level Architecture (HLA) defined product categories and allowed the possibility of multi-vendor training solutions. Without these first-generation learning technology standards, the costs and risks associated with acquiring and maintaining large-scale training systems might have dramatically slowed the technology's adoption.

These standards still heavily influence how training technologies are developed and deployed today, but we are in the midst of a new era characterized by ubiquitous computing and a wave of new learning technologies. From Amazon's Alexa to Kahn Academy to augmented reality, the way people learn is fundamentally changing. The old standards are no longer adequate, and a new set of standards is emerging – the last year alone saw the initiation of standards activities related to competencies and credentials; adaptive instructional systems; student data privacy and security; the Experience API (xAPI); and eBooks as platforms for learning. Standards efforts addressing human performance metrics and augmented reality are already in full swing, and others that will define how virtual reality, cloud computing, AI, big data, blockchains, 5G, and other technologies affect training are on the horizon.

This paper provides practical insights into the new wave of standards and its implications for instructional designers, product developers, trainers, and acquisition commands. It explains what the standards are, what problems they solve, and how they fit together. Implications for training organizations, product developers, systems integrators, and acquisitions commands are outlined.

ABOUT THE AUTHORS

Dr. Robson is a researcher, entrepreneur, and standards professional known for creative and disruptive innovation in industry and academia. He is co-founder and CEO of Eduworks Corporation, serves on the IEEE Standards Association Standards Board, and is currently developing transformative infrastructure for competency-based education, training, and talent management. In academia, Robby was an early advocate for undergraduate research, competency-based education, and web-based learning. In industry, he pioneered applications of machine learning and natural language processing to content analysis and creation. In the standards world, he is former chair and current vice chair of the IEEE Learning Technology Standards Committee (IEEE LTSC) and is chairing the conference subcommittee of the Industry Connections Industry Consortium for Learning Engineering (ICICLE). Robby holds a doctorate in mathematics from Stanford University.

Avron Barr serves as Chair of the IEEE's Learning Technology Standards Committee and has had a life-long interest in the impact of AI technologies on education and training. While a graduate student at Stanford, he helped develop some of the earliest adaptive e-learning software; edited the four-volume Handbook of Artificial Intelligence; and co-founded a Silicon Valley AI startup called Teknowledge. Since then, he has worked with dozens of companies, startups, government agencies, and NGOs to help them understand, explain, or market advanced software technologies. During the 1990's, Avron co-directed a study of the global software industry at Stanford's Graduate School of Business and taught in the Executive Education program there. In recent years, he's been on the Advisory Board for a major DARPA project on game-based training. He taught a popular freshman seminar at Stanford for ten years called The Business of the Internet. He currently consults on the Advanced Distributed Learning (ADL) Initiative Total Learning Architecture project, where his focus is on learning systems infrastructure and bridging the gap between learning science research and successful market innovation.

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INTRODUCTION

Military and corporate training technology has been heavily influenced by technical standards, whether *de jure* standards developed by accredited standards development organizations (SDOs) such as the IEEE Standards Association (IEEE-SA), standards developed by non-accredited SDOs such as the IMS Global Learning Consortium (IMS Global), or *de facto* standards promulgated by organizations such as the US Advanced Distributed Learning (ADL) Initiative. Standards, which in the paper includes all of the above, typically enable interoperability among systems by defining the structure, syntax, and semantics of data elements that the systems exchange. Engineers use these definitions to determine how to encode, transmit, receive, and interpret data. Prime examples of standards used in training technology include

- **The Shareable Content Object Reference Model (SCORM),** published by the ADL, is itself is an aggregation of IEEE and IMS Global standards (ADL, 2017). SCORM defines methods for developing and packaging training content for delivery in learning management systems (LMS) in ways that enable the content to be developed independently of the LMS (called *content portability*) and that enable basic reporting (e.g. quiz scores and time-in-lesson) and basic "sequencing," (e.g. instructing the LMS to provide the learner with a selectable table of contents or to determine which content to deliver next based on which learning objectives a learner has completed).
- **Distributed Interactive Simulation (DIS) and High-Level Architecture (HLA)**, both IEEE standards developed by the Simulation Interoperability Standards Organization (SISO) (SISO, 2018), enable models, events, and entities to be interoperably exchanged among collaborating systems. DIS is based on standard broadcast protocols (e.g. UDP/IP) used in networking, while HLA creates a federation in which each simulation can specify the information it will exchange.
- **Learning Tools Interoperability (LTI)**, one of many IMS Global standards that are heavily used by educational publishers and educational technology providers and now in products such as the Generalized Intelligent Framework for Tutoring (GIFT), enables an LMS to launch external tools in a new iframe or browser window and to exchange basic data with the tools (IMS GLC, 2017).

SCORM, DIS/HLA, and LTI are in common use today and have had significant commercial impact. As technical standards they are solutions to engineering problems, but in the larger context of learning technology they are better understood as solutions to market and business problems. SCORM arguably launched the multi-billion-dollar eLearning industry (PR Newswire, 2018); DIS/HLA has spawned dozens of companies and products in the modeling and simulation (M&S) space (Wikipedia, 2018); and LTI is one of several IMS Global standards that served to re-establish the supply chain that runs from educational publishers and technology providers to educational institutions to students (Robson & Barr, 2018).

Overtaken by Technology

Despite their success and continued use, the standards mentioned above are becoming obsolete due to new technologies, new architectures, and new business models. As is argued in (Robson & Barr, 2018), the need for content portability is diminished by the now dominant Software-as-a-Service / Cloud Computing / Web App model. Although Modeling and Simulation (M&S) systems still rely on DIS and HLA, and although educational technology providers still use LTI, developers in areas ranging from HR to health and finance are achieving the same (if not higher) levels of interoperability and data exchange capabilities by publishing JavaScript Object Notation Application Programming Interface specifications (JSON APIs)

without relying on domain-specific standards. In other words, much of what was once necessary for interoperability among enterprise systems, including training systems, is now handled by the standards, technologies, and architectures that comprise the modern Web. Legacy standards are often updated and revised, but it is reasonable to expect that the first wave of technical standards used by training systems will be replaced by a new wave, and there is ample evidence that the transition is in fact occurring. This paper presents the evidence, lays out a roadmap for standards development in learning technology, and discusses its implications.

The Infrastructure Needed for Learning Portability

Advances in technology have changed the ways people learn and are changing the ways training organizations deliver courses and manage learners. Prior to 2010, trainees would typically interact with only one institution, and all training was delivered and managed by an institutional Learning Management System. Today, learners often work with multiple institutions and with independent online providers of courses and credentials. Training organization are also moving past the limitations of LMS-based delivery, incorporating online offerings, including massive stand-alone simulations, adding AR and VR components, and attempting to move to competency-based approaches that include badges and other credentials that explicitly reference the knowledge, skills, and abilities a learner has acquired. In short, the old LMS-centric, single-provider model of training no longer applies, and we are also seeing fundamental changes not only in the way that training is managed and delivered at the institutional level but also in how it is designed and interacts with the learner in real time. These changes include AI-enhanced training products that are already on the market and are becoming more powerful and more prevalent. These new systems use AI to teach, coach, make recommendations, grade essays, monitor learners, and alert instructors about learners in distress. To do that, they need to monitor every aspect of the learners' online activity in real time.

The infrastructure used by training organizations is evolving from LMS-centric silos to more open and distributed ecosystems. Military projects such as Sailor 2025 (US Navy, 2017), the US Army's Synthetic Training Environment (STE) (US Army CAC-T, 2018), and the Air Force's Continuum of Learning (AETC, 2018) are emphasizing distributed blends of advanced technologies, and similar things are happening in corporate training (Bersin, 2017). As this transition unfolds, and as learners become less tied to single organizations or training systems, new tools and infrastructure will be needed to enable learners and learning results to move among training systems seamlessly and with minimal friction. The desired state is called *learning portability,* and achieving it requires learning activities, analytics engines, instructional agents, and other training systems to access and interpret new types of data, including:

- **Global and Lifelong Learner Histories**. Smart systems do a better job if they know as much as possible about the learner's learning objectives, history, interests, and preferences. This information must be available to all institutions and learning providers with which a learner interacts over the learner's lifetime.

- **Competency Frameworks.** Every organization has its own way of characterizing competencies and their mastery levels, but if learning is to be portable across organizations and training systems, then each such competency framework must be interoperable with all others.

- **Runtime data**. As systems get smarter and use more AI, they demand fine-grained data that describes exactly what the learner is doing at any time, and as learners engage simultaneously with multiple systems, this runtime data will need to be represented and shared in a standardized way. In addition, future systems will be required to expose these data in real time and to accumulate them for post-facto analysis.

Rain on the Data Parade

While schools, training departments, publishers, and online providers will need to expose more learner data to support increasingly powerful learning environments, they will also need to assure data security and they will need to comply with data protection laws and policies. As this paper goes to press, there is heightened public awareness of these needs and concerns, especially as it relates to social media around the globe. In the K12 education market, concerns about student data privacy in education brought down the $30 Million inBloom project (Herold, 2014). Moreover, data security must be accomplished in a heterogeneous computing environment that includes tablets, consoles, goggles, and other devices with varying functionality. Each category of device has different data capabilities and accesses networks in different ways, all of which makes it more difficult to assure privacy and

security. Thus, in addition to the need for ubiquitous, detailed, shared data about learners, there are also clouds on the horizon that could rain on the data parade and must also be considered in the development of standards.

A NEW WAVE OF STANDARDS ACTIVITIES

Stakeholders have initiated a significant number of new standards activities 2017 and 2018. These standards address the data interoperability requirements outlined above and are laying the groundwork for learning portability and the next generation of AI-enabled systems. In this paper, we concentrate on standards projects sponsored by the IEEE Standards Association (IEEE-SA). The IEEE-SA is a global standards development organization (SDO) under whose auspices DIS, HLA, and several components of SCORM were developed. We also mention standards developed by other relevant SDOs, including the IMS Global Learning Consortium (IMS Global), the World Wide Web Consortium (W3C), the International Organization for Standardization (ISO), and Schema.org, but we pay the most attention to the IEEE-SA because of its unique role as an SDO that:

- produces open industry consensus standards (OpenStand, 2018);
- operates at the leading edge of technology;
- is part of an organization (the IEEE) that includes hundreds of thousands of researchers and practitioners;
- includes learning technology standardization projects.

IEEE standards range from WiFi and Ethernet to electrical, power, automotive, industrial, civil, and software engineering. We focus here on the new IEEE-SA Standards Activities most relevant to the future shape of learning technology.

The Experience API (P9274.1.1)

Developed by the Advanced Distributed Learning Initiative and its contractors, including especially Rustici Software, the Experience API is an open source specification that enables any training system to report learner actions and assessment results to a "Learning Record Store" (LRS) where the data can be accessed by all systems. Unlike SCORM, the xAPI specification does not limit the type of actions and results reported. xAPI is designed to work with any number of training systems of any time (stand-alone, mobile, cloud-based, ...) and not just a single enterprise LMS. xAPI is already a de facto standard in many parts of the training world. A new IEEE LTSC standards project, chaired by Jonathan Poltrack of Veracity Technology, aims to formalize the current xAPI v.1.0.3 data model and communication protocol and related LRS requirements. Future standards are expected to address xAPI profiles, which define canonical ways of reporting on typical learner-system interactions within a community of practice.

Classification of Adaptive Instructional Systems (P2247.1)

Under the leadership of Dr. Robert Sottilare of the US Army Research Laboratory's Center for Adaptive Instructional Science (ARL, 2018), work has started on the first of several expected standards relating to adaptive instructional systems (AIS) – products that use AI to teach, coach, recommend, diagnose, and personalize learning. Dr. Sottilare organized a series of workshops in 2018 to explore the need for and nature of standards to support these AI-enhanced systems, including sessions at both the Intelligent Tutoring Systems Conference in Montreal and the AI in Education event in London. The first standard is slated to define the capabilities and categories of AIS with the intent of bringing clarity to a rapidly evolving product space. (Robson, Barr, & Sottilare, 2018).

Reusable Competency Definitions (P1484.20.1 revision)

Standards for representing and exchanging shared definitions of competencies have been around for a long time but have not been applied much outside of formal education. Competencies are used to define learning objectives, levels of mastery, job requirements, and prerequisites for learning activities. 2017 and 2018 saw a renewed interest in competency standards, motivated by competency-based training, mastery-based education, and credentialing initiatives (Credential Engine, 2018; C-BEN, 2018). The Postsecondary Education Standards Council (PESC) and the Credential Engine Project jointly initiated a major effort to crosswalk the data models developed by several standards organizations – comparing the data models element by element. In 2018, this effort produced a list of the common elements of these existing standards -- data elements that, with different names, were used to represent competencies and competency frameworks. In addition, the IMS Global Competency and Academic Standard Exchange (CASE) specification was publicly released in 2017. At the same time, the Credential Engine created its

own variant of the Achievement Standards Network (ASN) format for representing competencies. Jim Goodell from the US Common Educational Data Standards project (CEDS) is chairing a new standards activity that will result in a revision of the 10-year-old IEEE 1484.20 "Reusable Competency Definitions" standard, based on this list of common elements.

Standards for Ethically Aligned AI

As AI is becoming more prevalent and more useful, it is also raising numerous ethical concerns. The issues relate not just to learning systems but to any system, such as an autonomous vehicle or smart city, that is using AI to make decisions that directly and palpably affect people's lives. The IEEE-SA "7000 series" of standards aims to define how to develop AI ethically and responsibly. Within this series is an IEEE LTSC-sponsored project (P7004) that is developing standards for child and student data governance. With the recent introduction of the European Union General Data Protection Regulations (GDPR), there is a heightened awareness of issues of data governance and privacy in many industries and communities. The aim of the 7004 standard is to define specific methodologies to help users certify how they approach accessing, collecting, storing, utilizing, sharing, and destroying child and student data. The standard will include specific metrics and conformance criteria collected from trusted global partners, and will recommend ways that vendors and educational institutions can meet them (LTSC, 2018).

Standards for Describing New Learning Platforms

Training organizations continue to explore and adopt new delivery platforms. Each platform introduces new interoperability challenges that must be met to effectively use the platform for learning, some specific to learning and others more general. The IEEE LTSC has started two standards activities in this area:

Augmented Reality Learning Experience Model (ARLEM - P1589)
The ARLEM standards project, chaired by Prof. Fridolin Wild of Oxford Brookes University, is creating a standard model for describing learning environments in an augmented reality (AR) training system. An AR model describes a real-world environment, such as a shop floor, with video and audio augmentations that appear at specific places under specified conditions and that are aimed at helping a worker learn and/or perform a task. Today, training organizations build these models using an authoring tool supplied with the AR system, which means they must rebuild the model in its entirety when they replace the AR system with a newer one. The standard proposes a common syntax and semantics, so that devices and systems from different vendors can, to the extent possible, export and import each other's models.

Mobile Requirements for eReaders to Support Learning Application (P7919.1).
This new project, chaired by Dr. Robby Robson of Eduworks, is developing a standard that will enable developers, authors, publishers, and consumers to understand the learning-related capabilities and affordances offered by the software that is used to display eBooks and, in the future, other forms of mobile learning. For mobile content to work, its requirements must be matched to the capabilities of the platform. In this standard, content may range from an interactive traditionally organized document – the type of eBook one would buy on Amazon -- to a fully adaptive training system that includes adaptive content, contextualized chat, shared annotations, embedded simulations, and a full range of assessments. This IEEE project relates closely to work on the next generation of standards for eBooks – EPUB 3 – taking place within the W3C Publishing Business group and to efforts at the IMS Global Learning Consortium to standardize the use of two IMS Global standards in eBooks.

IEEE Standards Defining the Technology Landscape

In addition to standards specifically addressing learning technologies, IEEE-SA working groups are pursuing numerous activities that promise to change the information and communications technology landscape in ways that will profoundly affect training systems. These include:

Blockchains
Blockchains – famously first used for cryptocurrency – are now being widely applied to record and share transactions within a supply chain. They provide distributed ledgers that allow anyone (or anyone with permission) to record transactions in ways that are verifiable, immutable, and permanent – without requiring administration by a central authority. These properties offer clear advantages to future solutions for tracking financial transactions, for

electronic health records, for tracing food from farm to store to table, and, we would argue, for recording an individual's learning history.

5G

5G wireless technology is on the horizon and promises to provide ubiquitous, high-bandwidth, low-latency, high-capacity connectivity. What this new technology means for training systems is anywhere, anytime, any device, instant access to high fidelity games, simulations, and other virtual and constructive environments. Combined with of the Internet of Things (IoT), AI, AR/VR/MR, and brain-computer interfaces, 5G opens unbounded new possibilities for training. Connected devices could report their status to AIs, which could then identify imminent maintenance needs or enemy threats, notify warfighters, and immerse them in multi-person simulations to get them up to speed quickly on the skills they need to respond. This science fiction scenario may not be far from becoming a reality today. Even if this futuristic vision is slow to materialize, 5G is a standards-based technology that solves the connectivity problems in computer-based training that engineers have had to work around since the introduction of LAN-based training systems and 56K modems.

Mixed Reality

Virtual reality, augmented reality and mixed reality (together sometimes called "X-Reality") are the subject of many standardization efforts, both specific to their using in training and more generally. The ARLEM standard described above, for example, addresses the content portability problem in AR-based training. SISO-like standards that allow xR systems to be built from plug-and-play components may also make sense. Many research projects have demonstrated the potential application and impact of X-Reality technologies in training.

IoT, Symbiotic Autonomous Systems, Quantum Computing, Neural Networks, Fog Computing, …

The IEEE's various units often serve as incubators for new communities devoted to emerging technologies (IEEE, 2018). Blockchains, 5G and "Digital Reality" are some of these, but there are many other active tech-focused communities. Almost all of them are developing standards that lay the groundwork for the interoperable, effective, safe, and ethical application of these technologies in various markets, including education and training. There is likely no need to pay close attention to any of these future technologies specifically, but it would be remiss not to keep in mind that they are "out there." Any one of them could trigger yet another wave of new learning technologies and standards.

OTHER STANDARDS ORGANIZATIONS TO WATCH

There are several standardization efforts underway outside of the IEEE that are relevant to the shift to learning portability. We list here three organizations that are quite active in the learning technology standards and that in fact have published standards that have been broadly adopted:

Schema.org

As an organization, Schema.org is managed by Google, Microsoft (Bing), and Yandex (the Russian search engine). Their objective is to produce shared vocabularies that help authors embed metadata in Web pages in a way that will improve the accuracy of search engines. One metadata element defined by Schema.org is "Creative Works" which in turn includes an "educational alignment" element. Developed by the Learning Resource Metadata Initiative (LRMI, 2018), this element can link a learning resource to competencies defined within an educational framework. (Schema.org, 2018)

Newer efforts supported by LRMI and other organizations such as the Credential Engine (Engine, 2018) are underway to define additional schema for competencies and credentials. The schema.org connection brings learning-related metadata into the web technology mainstream and creates the possibility the major search engines becoming marketplaces for learning materials and activities. But more importantly, the schema.org metadata can be encoded as "linked data." Linked data systems incorporate computer-readable taxonomies that define the meaning of terms so that AI-enhanced products can correctly interpret and reason with the shared data. Forthcoming schema.org schema for competencies and credentials will support learning portability by creating interoperable ways for training systems to find, ingest, and publish competency frameworks and competency-based credentials.

IMS Global Standards

IMS Global is a significant SDO for education technology providers and consumers that has traditionally served the supply chain that runs from educational publishers to educational institutions to students at those institutions. IMS Global standards address accessibility requirements, methods for packaging content for LMS delivery, means to express questions and tests, and more recently standards for representing and exchanging competency frameworks (the IMS Global CASE standard) and for representing badges – the latter having been taken over from the Mozilla Open Badge Initiative. Several IMS Global standards are used in commercial training technology. For example, SCORM (ADL, 2017) incorporates IMS Global standards; the IMS Global Learning Tools Interoperability (LTI) standard has been used by the GIFT project to register applications with intelligent tutoring systems (ARL, 2018); and commercial assessment engines use IMS's Question and Test Interoperability (QTI) (IMS Global, 2018). As with other SDOs, much of the most recent work of IMS Global addresses problems associated with what we are calling learning portability: CASE, Open Badges, Caliper, and a new effort concerned with standardizing representations of learning pathways.

Simulation Interoperability Standards Organization (SISO) Standards

SISO is simultaneously an IEEE-SA SDO and an SDO accredited independently by the American National Standards Institute (ANSI). SISO is currently updating HLA and standardizing Human Performance Markup Language (HPML). HPML defines how results from simulations and other training systems are mapped to performance levels, i.e. it defines how to interpret data emitted by simulations in the realm of human performance. This is important because without it, these data just become a series of actions or measures with no meaning. XAPI takes the approach of reporting directly what a learner did and how the results were interpreted by the training system, whereas HPML reports the raw data and explains how to interpret. These complementary approaches can be combined, as is suggested by (Emond, 2017).

SUMMARY OF THE NEW WAVE OF TRAINING STANDARDS

Standards don't happen overnight. The consensus and approval process can take a year or more. Only then will conformant products start appearing in the marketplace. And unless customers start to insist on buying only conformant products, broad adoption may never happen. Only the marketplace can make a standard successful. Sometimes forward-looking market players establish acquisitions policies that accelerate the adoption of standards, both by creating an early market for conforming vendors and by demonstrating the benefits and savings of plug-and-play architectures. The US DoD's Instruction 1322.26, which covers the acquisition of training systems, is a prime example of a standards-accelerating acquisitions policy.

That said, we have seen a slew of new standards efforts starting in 2018. Table 1 summarizes the new wave of learning technology standards. It is organized in terms of the problems and opportunities stakeholders will be facing -- training managers, systems integrators, and product developers. The table also includes our best guess as to when we anticipate that these standards and the very first conformant products will emerge.

Problem	Standard	Timeframe
Sharing learner models across adaptive instructional systems	New projects underway (P2247)	Possibly by 2021
Publicly sharing and comparing competency frameworks	Multiple such standards exist now. These are to some extent being unified under IEEE P1484.20.1 and will be aided by new Schema.org schema.	Expected 2020
Sharing learner qualifications and credentials between organizations	IMS Global Open Badges, W3C Verifiable Claims, Credential Engine Credential Transparency Description Language (CTDL), future Schema.org schema.	Exist today. Expect to mature by 2022
Sharing learner activity data and evidence of learning other systems	xAPI and IMS Caliper, with some discussion of merging these. May be overtaken by JSON APIs. The P9274 series under development will help scope this for specific communities of practice	Exist now with new work by 2021
Easily plug new components such as social media, simulations, after action review,	Can be accomplished using combinations of standards (reference models) and published APIs.	Exist now and evolving

and analytics modules into an existing training ecosystems	Expect some vendor APIs to become de facto standards.	continually
Assure the security and privacy of data in accordance with evolving laws and regulations	Addressed by P7004 and laws such as GDPR. Security is included in many technical ICT standards but has not been addressed specifically in the context of training systems.	Laws are being put in place. Expect through 2025
Transparency of AI – ensuring that consumers understand what an AI is doing, where and how it can be properly applied, its potential biases, and its implications.	Addressed by the IEEE 7000 series.	Expect by 2022.
Sharing and controlling access to lifelong learning data, including granular data of the type needed by AI-based recommendation engines	Expected to be addressed later under P2247, after the problem of sharing learner models among intelligent tutoring systems is addressed. Other efforts and products like student-controlled secure learning lockers may arise.	By 2025.
Defining performance and outcomes measures	HMPL in simulations, and portions of competency representation standards such as CEDS, ASN, and IMS CASE that enable rubrics to be attached to competencies.	Exist today but expect to be further refined.
Training using mobile platforms	P7919.1 and the underlying EPUB standards.	By 2022
Training using X-Reality	P1589 is on example. We expect many other projects to develop.	Through 2025

Table 1: Emerging Learning Technology Standards

We anticipate that the above standards will work together to support adaptive instructional systems and future training environments, including those envisioned by the various branches of the military. Figure 1 attempts to show how the standards and technologies support training systems. In it, the blue boxes are technologies, the green boxes are the training systems, and the yellow boxes are standardization efforts. The arrows point from standards and technologies to the standards, technologies, and systems that use them. Thus, for example, reporting standards such as xAPI are incorporated into training environments but also work together with badge and credential standards (e.g. by reporting successfully completed activities which are then used to award badges) and platform standards, which in some cases require the implementation of an LRS as part of the platform.

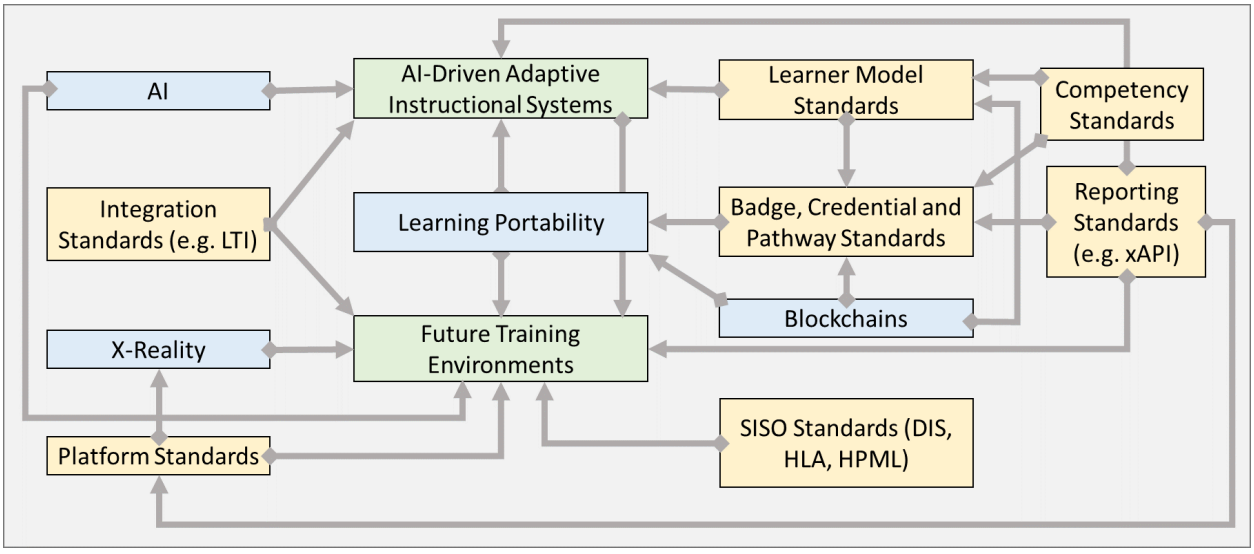

Figure 1: Relation Among Technologies, Standards, and Training Systems

IMPLICATIONS

Most people involved in developing and delivering training are not concerned with standards, but they are nonetheless affected by them. SCORM, for example, has influenced instructional systems design by enabling certain types of reporting and inhibiting others. Browser behaviors, which are largely determined by HTML standards, have also dictated much of the look and feel of today's first-generation eLearning and online training systems. Similar statements can be made about SISO standards with respect to simulations. This section discusses some of the implications we see for the new wave of standards discussed above.

Intelligent Tutoring Systems and AI

AI-enhanced products have already begun to appear in education and training markets. These include Adaptive Instructional Systems, personal assistants for students and teachers, robo-graders, and a variety of learning analytics products that monitor and analyze learner activity. Even more powerful AIs, in the form of Intelligent Tutoring Systems (ITS) and embedded agents have been demonstrated in the laboratory. In these products, AI algorithms personalize and optimize learning by developing models of the learner and making decisions about what material to present and how to present it. They monitor learner activity and can intervene with questions or hints.

To date, however, these products have mostly been designed as monolithic systems, i.e. as isolated data silos. While Intelligent Tutoring Systems have been recognized as highly effective training systems that can be incorporated into LVC environments, they have remained mostly on the sidelines due the difficulty and costs of developing these complex systems from scratch. The US Army Research Laboratory's Generalized Intelligent Framework for Tutoring program (GIFT), however, appears to be making headway towards creating a platform that can be used to efficiently develop and deploy ITS into training ecosystems (Sottilare, Brawner, Sinatra, & Johnston, 2017) (REF). The ability to exchange data about the learner (goals, history, competencies, context) among these AI-enhanced systems is key to their economics – increasingly so as these systems get smarter. The emerging set of learning technology standards provide that mechanism and will foster the development and widespread adoption of increasingly powerful AIs in education and training.

Instructional Design -- Developing Future Training Environments

Future training environments are envisioned as blending live, virtual, and constructive components supported by a plug-and-play development and deployment infrastructure that facilitates multi-vendor solutions and convenient data exchange among the components. The standards discussed in this paper are key to enabling this vision. However, the design and development of the learning activities themselves will require some adjustments on the part of the instructional design community. Whereas some systems, such as GIFT, have developed authoring tools that can hide some of the complexity, it is unlikely that adequate tools will be available for more complex environments as whole rather than for the separate systems that comprise them. The vision may be seamless integration, but there will likely be at least a few years during which there are gaps in technology and standards. Furthermore, since there is no real body of practice for designing the complex, AI-driven, X-Reality supported types of environments one sees in promo videos, development of learning activities that take advantage of the affordances of the new ecosystem will require new methods and new thinking about instructional design. Inventing tools to help authors create these advanced training systems cost-effectively is a top-priority research problem.

Limitations Imposed by Standards

The benefits to be gained from standardization are significant, but it is also important to keep in mind that standards unavoidably impose limitations as well. AIs, for example, can only use the data they are given. If the standards for learner models and learning data omit a type of data that is later found to be important, systems that use standardized data will be unable to make adaptations or recommendations based on the missing data element. If standards for mobile platforms do not consider the capabilities that 5G will bring, then training developed for these platforms may fail to take advantage of this emergent technology. If xAPI standards fail to include verbs for a type of learning action, then that type of action will never be reported in a way that can be captured by other systems. The best way to assure that forthcoming standards have minimal negative impact is for product developers and their customers to participate in the standards-making process.

Learning Engineering

The traditional enterprise learning ecosystem was relatively simple. Training organizations would deploy an LMS, integrate it with an HR system, a directory service, and their back-end services, and buy or build some content. The LMS handled almost every aspect of training management. This may still be how things work in some training organizations, but it will not be the case very much longer.
Consider this historical parallel: when PCs were first introduced, a company's marketing department started keeping all its data on spreadsheets. This was the first phase of automation. Over the years, marketing departments embraced database technology and then specialized Customer Relationship Management (CRM) systems. Today, the technology stack for any marketing organization includes additional tools for websites, email campaigns, analytics, social media, video distribution, and so on. This complexity arose not because new technologies were available but because they improved the efficiency and effectiveness of marketing and sales by replacing shotgun and *ad hoc* approaches into organized data-driven campaigns.

A similar and perhaps even more radical transformation is taking place in training for similar reasons, and this has created a need for professionals who understand technology and learning science and who are familiar with a wide range of available products, best practices, instructional design, and the applicable laws and regulations (e.g. about data and privacy). To this end, the training and education communities have recently begun to recognize the profession and discipline of *learning engineering* (ICICLE, 2018). Working with educators, instructional designers, and systems integrators, this new generation of learning engineers will build the future training environments that will exhibit the full and proper impact of the many new learning technologies and the standards discussed in this paper.

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DISCLAIMER

The views and interpretations expressed in this paper, and the characterizations of standards and organizations, are those of the authors and should be interpreted as such. This paper attempts to be objective but is necessarily heavily influenced by the experiences and views of the author.

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