Analyzing the Motivation for Adaptive Instructional System (AIS) Standards

Robert A. Sottilare, Ph.D.
Soar Technology, Inc.
Orlando, Florida
bob.sottilare@soartech.com

ABSTRACT

This paper examines the requirements, costs, and benefits of establishing standards and recommended practices for a class of education technology called an adaptive instructional system (AIS). AISs accommodate individual differences by tailoring instruction (educational and training experiences) to facilitate learner knowledge acquisition (Wang & Walberg, 1983; Tsai & Hsu, 2012). They guide one-to-one learning activities that exercise skills defined by learning objectives (Sottilare & Brawner, 2018), and they use artificial intelligence (AI) and other advanced technologies (tools and methods) to help people learn more effectively and efficiently (AIS Consortium, 2021).

The growing use of AISs in military training, pre-K, K-12, higher education, and adult learning contexts has prompted the AIS community (learners, instructors, instructional designers, system developers, testers and evaluators, and system providers) to initiate IEEE standards. An IEEE working group is managing the development of AIS standards and recommended practices under Project 2247. The initial focus of the Project 2247 working group was to develop a conceptual model of an AIS, its primary components and features. Other efforts have begun to focus on AIS interoperability standards to promote reuse and recommended practices for the fair evaluation of AIS performance capabilities.

While the motivation for AIS standards requirements may be evident to some, the contributing factors for the costs and benefits of standards has yet to be fully explored. Although infrequently considered by learning science researchers, factors can be as critical as the benefits accrued from effectiveness in improving the state-of-art and state-of-practice in both training and education. This paper will discuss recommendations for various standards and practices arising from the AIS community and analyze the business case for advancements and opportunities provided by each recommendation in a training and education context. Standards recommendations are grouped by the following categories: policy, authoring and curation tools, learner modeling, domain modeling, instructional strategies and assessments, and interface design standards.

ABOUT THE AUTHOR

Dr. Robert Sottilare is the Director of Learning Sciences and joined SoarTech in 2018 after completing a 35-year federal career in both Army and Navy training science and technology organizations. He has nearly 40 years of experience as a researcher, developer and evaluator of instructional technology and training systems. His experience spans government (US Army and Navy science & technology organizations), industry and academia. Dr. Sottilare is also the Founding Chairman of the Board for the Adaptive Instructional Systems (AIS) Consortium. His recent research focuses on intelligent solutions for analysis and adaptive instruction including learner and team modeling, automated authoring tools, AI-based real-time instructional management, and evaluation methods. At the US Army Research Laboratory, he founded and led the adaptive training science & technology program and is the father of the award-winning Generalized Intelligent Framework for Tutoring (GIFT), an adaptive instructional architecture. Dr. Sottilare is widely published with over 250 technical papers with over 2600 citations. He is a senior member of the IEEE and founding Chair of the IEEE AIS Working Group and the HCII AIS Conference and is a past Program Chair of the Defense & Homeland Security Simulation Conference. He is a past chair for the Technical Cooperation Program's Training Technology Panel and NATO Research Task Groups including the "Assessment of Intelligent Tutoring System Technologies & Opportunities" and the "Assessment of Augmentation Technologies for Improving Human Performance". Dr. Sottilare previously instructed graduate level courses on Intelligent Tutoring System (ITS) theory and design at the University of Central Florida.

Analyzing the Motivation for Adaptive Instructional System (AIS) Standards

Robert A. Sottilare, Ph.D.
Soar Technology, Inc.
Orlando, Florida
bob.sottilare@soartech.com

INTRODUCTION

This paper examines the requirements, costs, and benefits of establishing standards and recommended practices for a class of education technology called an adaptive instructional system (AIS). AISs accommodate individual differences by tailoring instruction (educational and training experiences) to facilitate learner knowledge acquisition (Wang & Walberg, 1983; Tsai & Hsu, 2012). They guide one-to-one learning activities that exercise skills defined by learning objectives (Sottilare & Brawner, 2018), and they use artificial intelligence (AI) and other advanced technologies (tools and methods) to help people learn more effectively and efficiently (AIS Consortium, 2021).

AISs are a group of learning technologies that include intelligent tutoring systems (ITSs), intelligent mentoring system (IMS), and intelligent instructional media. ITSs are computer-based systems that provide tailored instruction and feedback to learners, usually without intervention from a human tutor or teacher (Psotka & Mutter, 1988). Intelligent mentors are software-based agents that guide students toward their learning goals by continuously recommending next steps in their learning process (Baylor, 2000). An example of an intelligent mentor might be a recommender bot in a learning management system (Neumann, Lange, Klamma, Pengel & Arndt, 2020). Instructional media is a catch-all category for everything that is not an ITS or IMS, and includes tools and media that have AI-driven learning strategies (e.g., adaptive sequencing approaches for flashcard learning (Whitmer, Johnson & Marraffino, 2022)).

There is a long history of computer-based instructional research and development dating back to the 1960s, but until recently, there have been no AIS standardization efforts. In 2019, this changed with the approval of the IEEE Project 2247 Standards Working Group for AISs by the Learning Technologies Standards Committee (LTSC). Today, volunteer members of the IEEE Project 2247 Working Group continue to slog through a collaborative process that brings their expertise to bear on challenges in defining an AIS conceptual model, enabling interoperability and compatibility between AIS solutions, and supporting recommended practices for implementation, ethical use, and fair evaluation of AISs.

IEEE Project 2247 members are primarily AIS stakeholders (designers, developers, providers, researchers, buyers, and users) who have formed communities of interest and are contributing to the task of identifying standards requirements. While many are contributing, many more are not. As the AIS standards community debates the fine points of standards requirements and implementation, it is still not clear to many stakeholders how standards will impact their AIS solutions or how they might benefit the community. In the next few sections, this paper examines the economic outlook for AIS marketplace, the impetus for standards, and finally the costs and benefits of establishing and maintaining AIS standards and recommended practices. The goal is to uncover the potential/likely return-on-investment (ROI) for AIS stakeholders.

AIS INVESTMENTS

To begin analyzing the motivation for AIS standards, it made sense to look backward and forward to examine investments in AISs and related technologies. Our look back focused on the longevity and persistence of AIS research in the literature. The AIS literature is an indicator of longstanding interest in improving AIS tools and methods. A long history of AIS research investment would also be an indicator of a shared vision of the value of AISs. Our look forward focused on the economic trends and projections for the AIS marketplace. Healthy projections by economic analysts indicate that the AIS marketplace has a future and that the investment in standards has a potential ROI.

A Historical View of AIS Research and Education Technology Investments

Our historical view of AIS research examined the trends across the last 50 years for three AIS-related search terms. We selected three terms: 1) "intelligent tutoring systems" (an AIS technology), 2) "adaptive instruction" (an AIS process), and 3) "adaptive training" (another AIS process). We used Google Scholar on 25 May 2022 to conduct a bracketed search of each decade beginning in 1960 using these three search terms to identify the number of publications produced during each decade. Since publications are an indicator of completed research milestones, we used them as a measure of research investment during each decade. The results of our analysis (Figure 1) indicated upward trends with no horizontal or downward trends over this 50-year period. While not definitive or comprehensive, this data indicates growing research investments over a long period of time for intelligent tutoring systems, adaptive instruction, and adaptive training.

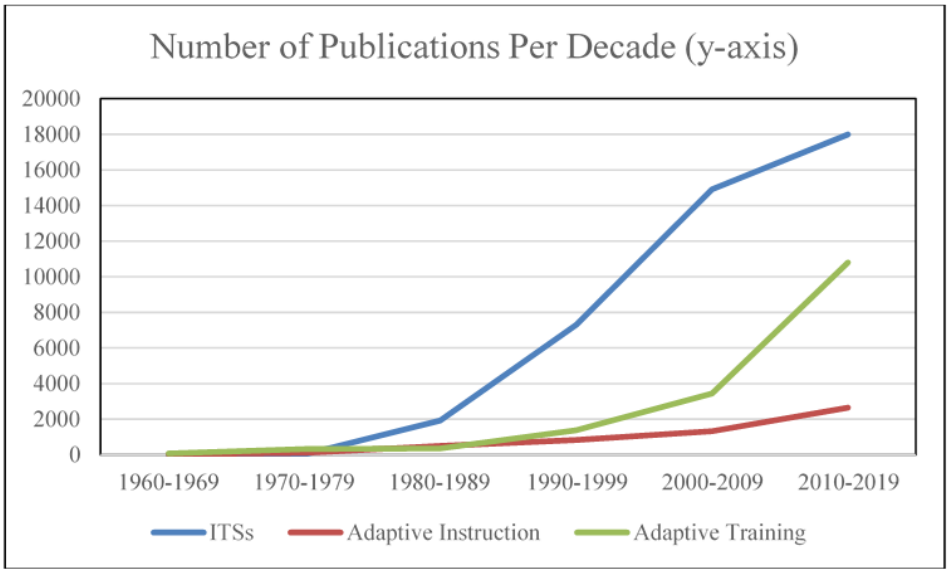

Figure 1. AIS-Related Publications Per Decade

In addition to growing research publications, we also examined growth trends in education technology from 2010-2020. HolonIQ (2022), a technology market intelligence firm, documented an over 35% compounded annual growth rate (CAGR) in education technology venture capital funding from $0.5B to 1.8B for the period 2010-2014. They also noted a greater increase of 44% CAGR with available funding growing from 1.8B to over $16B during 2014-2020. These high growth rates indicate the high confidence of investors in the education technology market.

Our goal for this historical analysis was to determine if investing in AIS standards will provide a payoff. Part of that decision process was answering the question "does AIS research and technologies have a history of growth?" and we have documented a growth rate with no horizontal or downward trends over a 50-year period. In the last 10 years, venture capital has continued to grow at a high rate. So, the AIS marketplace as part of the educational technology market is has been growing, but is it projected to continue to grow and at what rate?

Projections for the Future of the AIS Marketplace

The marketplace will determine if AIS products and services are in demand and will continue to remain in demand for the foreseeable future. Again, our goal in performing this economic analysis of the marketplace is to determine if investments in standardization will be worth the time investment.

Our time horizon for this economic analysis is 5-10 years into the future and the AIS-related technology areas we will examine include education technology, e-learning, online tutoring, and artificial intelligence (AI) in education.

While the AIS marketplace can be categorized into the following market segments, the granularity of data at this level is not yet publicly available:

- Components (products, solutions, and services)
- Deployments (cloud, fog, and edge computing)
- Enabling Technologies (e.g., competency modeling, natural language processing and other modal interfaces, virtual characters, AI and machine learning methods, learning management systems, assessment and intervention selection methods)
- Applications (e.g., content delivery systems, learning platforms, virtual instructors, authoring frameworks)
- End Use (e.g., pre-K, K-12 education, higher education, academic research, military training, corporate training, learners with disabilities, and marginalized populations)
- Learning Mode (adaptive, blended, social or collaborative, simulation-based, virtual instructor-led training)

It should be noted that the markets and segments in each of the four technology areas (education technology, e-learning, online tutoring, and AI in education) we examined are not mutually exclusive and in fact, their relationship to each other and scope overlap to varying degrees. AISs exploit many of the tools and methods noted below, but separate themselves from most of the market by using AI and other advanced technologies to tailor learning experiences based on a model of each individual learner (or team of learners), their learning goals, knowledge, interests, and learning gaps. The sampling of AIS-related technologies and their projected markets described below are intended to be illustrative rather than comprehensive.

We recommend a more comprehensive evaluation of each of the AIS market segments be conducted to collect information about past and projected investments to guide the investments and participation of government, industry, and academia in the future. For now, we examine related markets in education technology, e-learning, online tutoring, and artificial intelligence (AI) in education to project the longevity of the AIS market.

Educational technology (EdTech) is the marketplace of a broad group of technologies (tools and methods) that integrate hardware, software, educational theory, and strategies to facilitate learning (Robinson, Molenda & Rezabek, 2008). According to Grand View Research, the global EdTech market size was valued at $106.46 billion USD in 2021, and is expected to expand at a compound annual growth rate (CAGR) of 16.5% from 2022 through 2030. The trend toward greater use of eBooks and away from printed material is increasing the digital content available to support learning applications such as AISs.

E-learning (also known as smart education and learning) involves learning experiences (usually conducted on the internet) that use electronic/digital media (Pollard & Hillage, 2001) where successful learning depends on the self-motivation and discipline of individual learners to study effectively. Formal examples of e-learning environments include Massive Online Open Courses (MOOCs) on applications such as edX, Coursera or Futurelearn; virtual learning environments (VLEs) such as Canvas or Blackboard. Informal learning services include video streaming services, such as YouTube where information is provided, but no assessments are conducted. Trends show e-learning expanding in the K-12, higher education, and corporate training segments of the market while capabilities are expanding from individual learning to collaborative learning where two or more people learn or attempt to learn something together (Dillenbourg, 1999).

There is rising demand for interactive learning tools and methods that are intelligent (e.g., tailored learning), flexible (e.g., mobile learning), and engaging (e.g., gamification). In 2014, about one-third of college students took at least one online course (Babson Survey Research Group, 2014) rising to nearly 52% in 2020 (Hill, 2021). The global e-learning market size was valued at $182.8 billion USD in 2019 and is expected to grow at a CAGR of 17.9% from 2020 to 2027 (Grand View Research, 2022). According to Statista (2022), the global e-learning market was approximately 250 billion USD in 2020 and was composed primarily of online e-learning, learning management systems (LMSs), mobile e-learning applications and services, and virtual classrooms.

Improving accuracy in modeling learner competency, performance, and engagement are potential drivers of intelligent online tutoring. The rapid transition of AIS capabilities to smartphones is a significant factor in enabling flexible, anywhere, anytime learning. The merging of online tutoring services with artificial intelligence in education technologies will provide high value learning experiences that support accurate assessments and optimal learner

interventions. The global online tutoring services market size was valued at 6.57 billion USD in 2021 and is expected to grow at a CAGR of 14.7% from 2022 to 2030 (Grand View Research, 2022). The global AI in education was valued at 1.1 billion USD in 2019 and is forecasted to grow at a CAGR of 32.9% to $25.7 billion USD in 2030 (Grand View Research, 2019).

Based on this analysis, the economic outlook for AISs remains highly positive with trends of increased use (no horizontal or downward trends), improved capabilities, expanding user groups, and an expanding market through 2030. Having satisfied the question about the longevity and viability of AISs, we move on to the rationale for AIS standards, recommended practices, and other forms of technical standards in military training systems in the next section.

IMPETUS FOR AIS STANDARDS IN MILITARY TRAINING SYSTEMS

Technical Standards

A *technical standard* is an established norm or requirement for accomplishing recurring technical tasks (e.g., design, development, testing and evaluation tasks) where standard heuristics (rules), conditions, guidelines or characteristics for system production and maintenance processes. Technical standards may include definitions (terms of reference), classification of system components, development procedures and guidance, recommended practices, test procedures, physical specifications (e.g., size, material), system performance, and other measures of system fitness or acceptability (Millerand & Baker, 2010). Technical standards are also important enablers for system compatibility and interoperability (Lehr, 1995).

In general, standards have many benefits. Uniform standards and practices can improve task efficiency, the reuse and interoperability of system components, and reduce design, development, testing, and maintenance costs. In other words, standards ensure the safety, quality and reliability of products and services. The US military has a long history of both internally defined standards (e.g., MIL-SPEC parts) or in partnership with external standards organizations such as the Institute for Electrical and Electronics Engineers (IEEE; e.g., Project 1278 Distributed Interactive Simulation standards). Next, we examine a brief history of activities leading to the need for standards in military training systems.

A Historical Perspective on Military Requirements for AIS Standards

In January 2011, the U.S. Army's Training and Doctrine Command published their vision for adaptive training and education in the Army Learning Concept (ALC) for 2015. The ALC defined requirements for adopting emerging AIS technologies to create a state-of-the-art adaptive training program and capabilities. The ALC action plan included goals to develop ***standards, protocols, and guidance for AIS technologies*** (tools and methods) to accelerate learning and improve the effectiveness of instruction. In 2017, the ALC was updated to the ALC for Training & Education (ALC-TE) to project a vision and requirements for the period 2020-2040 (TRADOC, 2017). The ALC-TE describes a continuous, adaptive learning enterprise that facilitates a career-long continuum of learning. Under the adaptive training and education concept, the ALC-TE calls for adaptive instruction that produces agile learning, responds quickly to learning gaps, delivers instruction at the point of need, is continuous and progressive, enables the acquisition of progressively higher skills, and is outcomes based to meet the Army's skills needs and capability goals.

In March 2011, a group of government researchers from each of military services, DARPA, the Advanced Distributed Learning (ADL) Initiative, and the Department of Education met at Texas A&M University to discuss the state-of-the-art and the state-of-practice for adaptive training technologies, and formulate strategies for exploiting current and emerging capabilities in military training systems. In reviewing various adaptive training research programs and initiatives, the group noted the diversity of technology and that the ***lack of interoperability standards and reuse*** across these technology prototypes and products. Several recommendations focused on additional research requirements and expanding research to include efforts outside of the United States. The outcome of these discussions was captured in a report to the Department of Defense Human Systems Community of Interest (Goldberg & Sottilare, 2011) which provided a set of conclusions and recommendations including a few that highlight the need for standards:

- Instructional models were seen as a major hurdle and the group recommended research and the development of ***guidelines*** on the relationship between trainee performance diagnosis and the selection/implementation of any ensuing instructional method

- The inability for domain experts to create adaptive training using current ITSs resulted in a recommendation to research and develop easy-to-use authoring tools and ***standardized processes*** to create and maintain adaptive courses
- There was general agreement that competency and knowledge states were key elements in trainee models, but research was needed to quantify the impact of other trainee model states (e.g., attention, emotions) and ***standard methods*** of assessment for relevant states

In April 2012, adaptive training research at the Army Research Laboratory – Simulation & Training Technology Center (STTC) produced an initial prototype of the Generalized Intelligent Framework for Tutoring (GIFT; Sottilare, Brawner, Goldberg & Holden, 2012; Sottilare, Brawner, Sinatra & Johnston, 2017), an open-source AIS software architecture that enables the design, development, deployment, testing, evaluation, and research of AISs, AIS components, and learning theories. Developers continue to add capabilities to GIFT and design principles used to create GIFT have been a model for AIS standards development within IEEE Project 2247. Until recently, GIFT has been primarily a tool for military training. However, interest in using GIFT for pre-kindergarten learning, K-12 education, higher education (college and university), and corporate training is on the rise. Recently, the AIS Consortium, a not-for-profit business association accepted a version of GIFT for commercial development. This forked baseline of GIFT is known as the Global Learning Toolkit (GLT) and will be used primarily as an open-source baseline for non-military training domains.

In October 2012, the NATO Science & Technology Organization approved the charter for a research task group (RTG) under the Human Factors & Medicine (HFM) Panel to explore ITS technologies. The "Assessment of Intelligent Tutoring System Technologies and Opportunities" RTG (HFM-237) kicked off in 2013 and included participants from Canada, Germany, Italy, Netherlands, United Kingdom, and United States. The impetus for forming HFM-237 was the findings of the NATO Training Group's working group on Individual Training and Educational Development (IT&ED) who identified substantial efficiencies could be achieved using computer-based instructional technology.

This group identified both reduced costs and enhanced training effectiveness as potential opportunities. The RTG examined the literature and activities in countries within and outside of NATO to discover the background, opportunities, and limits of ITS technologies (tools and methods). Expert lecturers and a review of the literature, examination of current and emerging research, and prototype development by the RTG members identified challenges in four major areas: authoring (development), ***standardization***, data analytics, and adaptive interfaces. The RTG completed their mission in 2017 and published a technical report (Sottilare et al, 2018) with significant findings and standardization recommendations:

- Currently, there are ***no standard processes, models, or components*** for ITSs, the RTG recommends standardization of ITS services that may be easily consumed by instructional systems
- The ***development of standards*** to promote ITS reuse and interoperability will have a major impact on the affordability of ITSs
- While nearly all ITSs have models for learners, instruction (pedagogy), and domains, these models and their interaction differ from tutoring system to tutoring system, and the ***lack of standards*** diminish opportunities for reuse of frameworks, processes, models, and components.
- Increasing ***interoperability*** will ease the integration of ITSs with other ITSs, existing training infrastructure and other educational systems (e.g., edX), promote reuse of scenarios, and reduce authoring time and cost
- Candidates for ***ITS standardization*** include learner models, instructional strategies with high degrees of effect in the literature (e.g., worked examples and error-sensitive feedback), open-source frameworks (e.g., Generalized Intelligent Framework for Tutoring – GIFT), inter-module message sets to support standard communications and promote component reuse and modularity, and the experience application programming interface (xAPI); note that the xAPI is now a standard (reference: IEEE Project 9274)

In 2016, the Air Force solicited research for a Competency-based Adaptive Training System (CATS) concept through the SBIR program. The goal of the CATS concept was to improve the efficiency and effectiveness of warfighter training and included requirements for personalized content and learning events, a library of learning opportunities, methods to continuously evaluate performance, models of learners' domain competency, and a demonstration in an operational environment. Since the CATS concept integrated a learning content management system (LCMS), a competency management system (CMS), and a learning management system (LMS), it was important to identify

CATS ***data standards for storing, searching, retrieving, and moving data*** around the CATS software architecture. The authors of this paper are unaware of any formal standards influenced by this project.

Today, much of the military training infrastructure continues to be minimally adaptive. Minimally adaptive training systems intervene with learners of equivalent performance identically, present all users with the same initial content, provide prescriptive interventions based only on assessed performance, and use the same interventions for common errors for all users. In other words, these systems generally don't tailor events or content based on the capabilities or needs of the trainee. For the most part, existing systems mainly model only learner knowledge. However, AISs and related intelligent technologies are becoming more common in military training systems, and researchers are breaking new ground to define interoperability between AISs and military training systems that enable external AISs to drive the tailoring of content difficulty and interventions with trainees (Sottilare, Hoehn & Tanaka, 2019). Next, we examine current military requirements for AISs and related intelligent technologies and provide a sample of military requirements for capabilities such as autonomous virtual tutors and mentors, adaptive serious games, automated scenario generation and experimental testbeds.

Recently, the U.S. Army Combat Capabilities Development Command's Soldier Center solicited AIS research and development solutions under its Broad Agency Announcement (BAA) Solicitation Number W911QY-20-R-0022. The U.S. Army has a need to leverage technologies like artificial intelligence (AI), data analytic tools, machine learning (ML), augmented reality, and distributed computing to improve the effectiveness and reduce the cost of executing collective training events. This requirement includes methods to model team competencies performing collective tasks, and competency assessment requires standard measures of team performance, methods to predict team success based on previous achievements during individual and team experiences (e.g., job assignments, training, education). This indicates use and validation of IEEE Project 9274 standards for the xAPI, and new guidelines for measuring team performance for cognitive and physical tasks.

In 2021, the U.S. Army, under the A214-036 Direct to Phase II SBIR topic, funded research for an integrated virtual human-adaptive instructional system (VH-AIS) capability. The integration of VH capabilities to support one-to-one tutoring implies the need for interoperable solutions that include standard messaging between the VH application and the AIS architecture to facilitate VH perceptions of human learner states and VH actions that include verbal and non-verbal behaviors (e.g., speech and gestures). Standards such as those defacto standards (e.g., module specifications and inter-module message types and formats) established by the developers of the GIFT architecture are being considered formally under the IEEE 2247 standards project.

Standards for the integration of external systems were also considered under the GIFT project. A standard gateway established norms for passing data from external systems into and out of GIFT. This includes several hardware and software-based sensors, external training platforms (e.g., Virtual Battle Space), and now there is a need for a standard to describe interface specifications for VH capabilities (e.g., University of Southern California-Institute for Creative Technologies' Virtual Human Toolkit or commercial products like the Media Semantics People Builder). Standard protocols are needed to communicate a variety of VH speech and gestures, and describe VH perceptions (e.g., classification of learner emotional states).

In 2021 and 2022, the Office of Naval Research (ONR) invested in the research and development of game-based methods to accelerate skills for strategic and tactical decision making under SBIR Phase I & II Topic N211-082. There are several instructional and learning strategies that have been documented to support more efficient or accelerated learning, but few stand out in terms of their broad application within serious games. As recommended to the DoD Human Systems Community of Interest in 2011, the development of ***guidelines*** for trainee performance diagnosis and the selection/implementation of any ensuing instructional strategy would be helpful in driving the consistent application of learning theory.

Based on this review of requirements documents and study recommendations, it is evident that the U.S. DoD and its component services recognize the effectiveness and efficiency potential of tailored training experiences over traditional training methods, and have begun to adopt AIS technologies for use in their training infrastructure. Based on projections, it is expected that the market will continue to drive innovation and the affordability of AIS solutions over the next ten years (Grand View Research, 2022).

COST & BENEFITS OF AIS STANDARDS

Our goal in examining costs, benefits, and return-on-investment (ROI) in this section is to provide a cost analysis model that includes a process and exemplar to be used as a guide by individual organizations to assess their investment in approved standards. ***A real analysis that includes both quantitative and qualitative measures should be performed by each organization seeking to implement any AIS standard***. Cost analyses examine the resources needed and opportunities that must be sacrificed to take a specific course of action and is contrasted with the value, benefit, or utility that course of action is likely to provide. Costs and benefits are usually measured in monetary terms, but measures of productivity, operational effectiveness, health, quality of life, morale, and human life are also fair game as variables of interest. Levin (1983) identified five classes of elements within a cost model, but for our AIS standards cost analysis model, the personnel costs are most relevant, and specifically, subject matter experts (SMEs) for standards development, and computer engineers for standards implementation make up the bulk of the costs.

For our simple example, we analyzed the costs and benefits of developing, balloting, and implementing a single AIS interoperability standard within a single training system. The following assumptions are relevant to our sample analysis: 1) labor rates for developing, balloting, and implementing any standard are equivalent, 2) benefits are enumerated in terms of cost savings (reduced task costs) and cost avoidance (eliminated task costs), 3) since labor rates are assumed equivalent, costs and benefits will be stated in terms of full-time equivalents (FTEs), 4) the development and balloting lifecycle for a single standard is assumed to be three years, 5) the standards development team is assumed to be 10 people working 10% FTE for a total of 1 FTE per year for 3 years, and the balloting group is assumed to be 30 people working 2% FTE for a total of 0.6 FTE, 6) convenience is a factor in that organizations that have in-house expertise may elect to develop a unique solution based on an available standard and those who do not have the in-house expertise may elect to purchase a commercial solution.

An AIS interoperability standard is expected to facilitate integration of future capabilities into existing training systems and the modularity of components developed to this standard are expected to facilitate plug and play solutions for learner models, instructional models, domain models, and interface models for learners and external systems. The development and balloting process are borne by the community, so it is fair to state that the cost for an approved standard is zero for many organizations. Their main cost is implementation and that will vary from system to system depending on the complexity and initial modularity of the system. Assuming standard implementation costs are "x" FTEs, and the value or benefit of the implementation reduces integration costs "y" by 20%, then the ROI for an individual organization would be:

- ROI = (Value of Result – Cost of the Result)/Cost of the Result = (0.2y – x)/x
- If x= 1 FTE and y = 2 FTE per new capability integration, and there are 5 integrations in the first year then the ROI after one year would be:
- ROI = ((0.2*2 FTE/integration*5 integrations)-1 FTE)/1FTE = 100%

Finally, we examined ROI in the context of a specific segment of the military training community. According to FlightGlobal Military Simulator Census (CAE, 2021), the total number of worldwide aviation military simulators in 2021 was 2863 with 1524 simulators in the United States. The cost avoidance associated with a 100% ROI for 2863 simulators is significant and at this ROI, our assumption that standards development and balloting costs are insignificant compared to implementation costs is valid. The next section of this paper explores additional considerations for the development of AIS standards.

ADDITIONAL CONSIDERATIONS FOR AIS STANDARDS ACTIVITIES

As noted above, each organization should conduct a cost-benefit analysis to capture rationale specific to their circumstances and strategic goals. In thinking about your own circumstances, we refer to a recent strengths, weaknesses, opportunities, and threats (SWOT) analysis (Sottilare & VanLehn, 2022, *in press*) conducted as part of an overall examination of ITS technologies. A SWOT analysis is a strategic planning method used to help a person or organization identify strengths, weaknesses, opportunities, and threats related to an area of their business where strengths and opportunities are considered helpful to achieving a strategic objective, and weaknesses and threats are considered harmful to achieving a strategic objective (Valentin, 2001). SWOT analyses are sometimes called situational assessments or situational analyses. The following elements of the Sottilare & VanLehn analysis are

relevant to the question of standards development investments discussed in this paper, and focus on the perspective of SWOT analysis from a resource-based perspective.

Designing AISs for Sustainability

AISs are often designed to be effective instructors rather than easy maintenance or component reuse. This was considered an AIS weakness in the SWOT analysis. AISs are often poorly documented, making it difficult to pass courseware security scans required by many military institutions. The ability to reuse components from one AIS in another AIS is currently nearly 0% due to the lack of interface and data standards. Many AISs have four common models for learners, instruction, domain knowledge, and user interfaces, but many vary in how and where their software architectures process data. A more effective design that still promotes AIS developer innovation is to standardize a set of common services (e.g., assessments, instructional interventions). Defining required services without specifying where the services reside or where they process learner data could reduce the standards development burden, but still enable shared services and a marketplace for such services.

Benefits of Authoring Tool Standards

Authoring tool standards were considered opportunities within the Sottilare & VanLehn SWOT analysis. Authoring tools are used to create adaptive courses or lessons within AIS frameworks (e.g., GIFT, AutoTutor, Cognitive Tutor). In many cases, authoring tools have a high degree of specificity and uniqueness. Standards and recommended practices for AIS authoring processes and services could be useful in streamlining authoring processes and in easing the transfer of AIS courses from one framework to another. From a resource perspective, authoring tool standards could greatly reduce the time required to create effective adaptive instruction (courses or lessons). Authoring tasks are the most skill and time intensive tasks related to the design, creation, testing, and deployment of AISs.

Benefits of AIS Interoperability Standards

Common interface and data standards for AISs will provide an opportunity to reuse courses, components, models (learner, team, instructional, domain, and interface) and subsystems from one ITS to another. Among the markets with large training infrastructure investments, AIS interoperability standards could enable the augmentation of existing training systems by adaptive instructional logic. This would alleviate the need to replace or totally redesign existing systems to take advantage of the adaptive features of AISs (Sottilare, Hoehn & Tanaka, 2019).

Benefits of AIS Evaluation Standards

Kulik and Fletcher (2016) conducted a meta-analysis of findings from 50 controlled evaluations of ITSs and the median effect in the 50 evaluations reviewed raised test scores 0.66 standard deviations over conventional methods. In this case, the baseline was traditional classroom instruction, but other studies have used other control groups. While many AISs have been empirically demonstrated to be as effective as expert tutors (VanLehn, 2011), the methods used to support evaluations usually vary. A recommended practice would be advantageous in guiding evaluation processes and easing the task of comparing results from various evaluations. It would also allow other researchers to duplicate the evaluation process and validate previous research results.

Benefits of Standardized Certifications from AIS Experiences

There already exists a standard for documenting achievement under IEEE Project 9274, Experience Application Program Interface (xAPI). However, the certification process, the method for issuing certificates of learning achievement, is not yet globally standard. This inhibits the transfer and acceptance of certifications when someone moves from one job to the next in another geographic area. While many DoD organizations share common achievement and certification processes within the services, the movement of military personnel to the civilian sector at retirement or separation may limit service members who apply for high stakes civilian positions. Maintaining standard achievement and certification models may facilitate the demonstration of job readiness credentials in the civilian sector. The next section discusses recommended next steps for AIS standards and recommended practices development.

NEXT STEPS

In this paper, we made a case for AIS standards by exploring historical AIS investments and projecting future investments. We also examined the historical impetus for military training standards, provided a methodology for assessing ROI for standards development in your organization. We discussed a SWOT analysis of AIS technologies and made recommendations for areas where the military could benefit the most from standards and recommended practices. We wrap our investigation of the benefits and cost of AIS standards by make a series of recommendations to the military training community.

First, we reiterate the need for each organization to assess their ROI for standards development in lockstep with their strategic objectives and their product lines and services. Next, if your organization decides to participate and shape AIS standards and recommended practices, we recommend a deliberate strategy for your participation. Investigate the scope of each activity (e.g., project) within working groups and subgroups to determine what is and is not relevant to your organizational interests. Our third recommendation is about educating yourself about AIS tools and methods so you have a better understanding about where standards could be beneficial to your organization, your stakeholders and customers, and the military training community.

Our fourth recommendation is to build on some of the ideas in this paper, and then come back to IITSEC next year to share your thoughts on the importance of standards. Finally, we recommend you dip your toe into standards and try a small level of participation. You have an opportunity to participate in working groups to help shape relevant standards without the requirement to be an IEEE member. Only members of the standard balloting group must be IEEE members so jump in and participate at whatever level you and your organization are comfortable.

ACKNOWLEDGEMENTS

The author wishes to acknowledge the contributions of the education and training communities for the development of AIS capabilities, standards, and recommended practices. Special thanks go to all the volunteer experts within the IEEE Learning Technologies Standards Committee and specifically those leaders supporting IEEE Project 2247 for AIS standards. Standards and recommended practices are shaping AIS conceptual models, AIS interoperability, AIS evaluations, and the ethical use of AISs.

REFERENCES

AIS Consortium (2021). Adaptive Instructional Systems defined. In the Charter of the Adaptive Instructional Systems (AIS) Consortium. Approved 6 January 2021.

Babson Survey Research Group (2014). Survey of College Students Taking Online Courses.

Baylor, A. (2000). Beyond butlers: Intelligent agents as mentors. Journal of educational computing research, 22(4), 373-382.

CAE (2021). FlightGlobal Military Simulator Census. Retrieved from: https://www.flightglobal.com/reports/military-simulator-census-2021/146804.article

Dillenbourg, P. (1999). *Collaborative learning: Cognitive and computational approaches. advances in learning and instruction series*. Elsevier Science, Inc., PO Box 945, Madison Square Station, New York, NY 10160-0757.

Goldberg, S. & Sottilare, R. (2011). Summary of the Department of Defense Adaptive Training Workshop. Sponsored by the DoD Human Systems Community of Interest. Conducted at Texas A&M University, College Station, TX.

Grand View Research (2022). Smart Education and Learning Market Size, Share & Trends Analysis Report. Retrieved 20 April 2022 from: https://www.grandviewresearch.com/industry-analysis/smart-education-learning-market.

Hill, P. (2021). Alternative View: More than 50% of US Higher Ed students took at least one online course in 2019-20. Retrieved 20 April 2022 from: https://philonedtech.com/alternative-view-more-than-50-of-us-higher-ed-students-took-at-least-one-online-course-in-2019-20/

HolonIQ (2022). Global Education Technology in 10 Charts. Retrieved from: https://www.holoniq.com/.

Lehr, W. (1995). Compatibility standards and interoperability. In *Standards policy for information infrastructure* (pp. 123-147). MIT Press.

Levin, H.A. (1983). Cost-Effectiveness: A Primer. Sage Publications, Beverly Hills, California.

Millerand, F., & Baker, K. S. (2010). Who are the users? Who are the developers? Webs of users and developers in the development process of a technical standard. *Information Systems Journal*, 20(2), 137-161.

Neumann, A. T., Lange, P. D., Klamma, R., Pengel, N., & Arndt, T. (2020). Intelligent mentoring bots in learning management systems. In *Learning Technologies and Systems* (pp. 3-14). Springer, Cham.

Pollard, E., & Hillage, J. (2001). *Exploring e-learning*. Brighton: Institute for Employment Studies.

Psotka, J., Mutter, S.A.: Intelligent Tutoring Systems: Lessons Learned. Lawrence Erlbaum Associates, Hillsdale (1988). ISBN 978-0-8058-0192-7

Robinson, R., Molenda, M., & Rezabek, L. (2008). Facilitating learning. *Educational technology: A definition with commentary*, 15-48.

Statista.com (2022). Global E-Learning Market. Retrieved from: https://www.statista.com/statistics/1130331/e-learning-market-size-segment-worldwide/

Sottilare, R. A., Brawner, K. W., Goldberg, B. S., Holden, H. K. (2012). The Generalized Intelligent Framework for Tutoring (GIFT). Concept paper released as part of GIFT software documentation. *U.S. Army Research Laboratory— Human Research & Engineering Directorate (ARL-HRED)*, Orlando, FL, USA.

Sottilare, R., Brawner, K., Sinatra, A., Johnston, J. (2017). An Updated Concept for a Generalized Intelligent Framework for Tutoring (GIFT). *US Army Research Laboratory*, Orlando, FL, USA.

Sottilare, R., Brawner, K. (2018, June). Component Interaction within the Generalized Intelligent Framework for Tutoring (GIFT) as a Model for Adaptive Instructional System Standards. In the Proceedings of the *14th International Intelligent Tutoring Systems (ITS) Conference*, Montreal, Quebec, Canada.

Sottilare, R.A., Fletcher, J.D., Skinner, A., Perez, R., Durlach, P., Zotov, V. & Alexander, T. (2018). NATO Final Report of the Human Factors & Medicine Research Task Group (HFM-RTG-237), Assessment of Intelligent Tutoring System Technologies and Opportunities. *NATO Science & Technology Organization*. DOI: 10.14339/STO-TR-HFM-237. ISBN 978-92-837-2091-1.

Sottilare, R., Hoehn, R., & Tanaka, A. (2019, December). Adapting existing simulation architectures to enhance tailored instruction. In Proceedings of the *Interservice/Industry Training Simulation & Education Conference,* Orlando, Florida.

Sottilare, R. & VanLehn, K. (2022, *in press*). SWOT Analysis of Intelligent Tutoring Systems (ITSs). Design Recommendations for Intelligent Tutoring Systems: Volume 10 - Strengths, Weaknesses, Opportunities, and Threats Analyses of ITSs. U.S. Army Combat Capabilities Development Center, Orlando, Florida.

Tsai CC., Hsu CY. (2012) Adaptive Instruction Systems and Learning. In: Seel N.M. (eds) Encyclopedia of the Sciences of Learning. Springer, Boston, MA. https://doi.org/10.1007/978-1-4419-1428-6_1092

Training & Doctrine Command (TRADOC; 2011). The U. S. Army Learning Concept for 2015. TRADOC Pamphlet 525-8-2.

Training & Doctrine Command (TRADOC; 2017). The U. S. Army Learning Concept for Training & Education (2020-2040). TRADOC Pamphlet 525-8-2.

Valentin, E. K. (2001). SWOT analysis from a resource-based view. *Journal of marketing theory and practice*, *9*(2), 54-69.

VanLehn, K. (2011). The relative effectiveness of human tutoring, intelligent tutoring systems, and other tutoring systems. *Educational psychologist*, *46*(4), 197-221.

Wang, M. C., & Walberg, H. J. (1983). Adaptive instruction and classroom time. *American Educational Research Journal*, 20(4), 601-626.

Whitmer, D. E., Johnson, C. I., & Marraffino, M. D. (2022, July). Examining Two Adaptive Sequencing Approaches for Flashcard Learning: The Tradeoff between Training Efficiency and Long-term Retention. In International Conference on Human-Computer Interaction. Springer, Cham.