Applying Standards and AI to Educational Technology: The IEEE Actionable Data Book Project

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1 Introduction

In the United States and other developed countries, new products built on emerging technologies such as tablets, mobile devices, cloud-based services and eBooks have generated widespread discussion about disruptive change in education at all levels. Typical questions raised include:

- Should the classroom be flipped using online video [1]?
- Can textbooks be replaced by open educational resources [2, 3]?
- What can children learn online on their own, and how can their families help?
- Can student advancement in school be tied to competence instead of cohort?
- Can a professor effectively teach 10,000 students at once in a MOOC [4-6]?
- Are automated assessments as good as human teachers [7-9]?

Although significant change is now occurring in the United States, especially in higher education, the potential for change and innovation may be even greater in the developing world. As has been demonstrated in mobile and Internet technologies, countries with less advanced infrastructures and fewer established policies and institutions can leapfrog the West in both quality of service and speed of deployment. In addition, developing countries have requirements and constraints that can lead to disruptive innovations that would not be developed in the West. An example of this may be found in the history of radio [10]. As the story goes, post-world war II Germany was given a very limited portion of the regulated radio spectrum. They therefore started using unregulated high frequencies. AM did not work well there, so they used FM. It turned out that FM had superior sound quality and became the dominant technology for quality radio.

In this context a central question is: *How can developed and developing countries collaborate to take advantage of the strengths of each?* In this paper we argue that fruitful collaboration can take place in the area of standardization and give a concrete example of how requirements from Bali spurred innovation and how standards activities in the area of eBooks may provide solutions. But first we examine in general terms the technological and related standards landscape that is emerging in eLearning.

2 Changes in eLearning Infrastructure

Today, commercial eLearning sales in the United States are dominated by two product categories, "content" (e.g. course packs and supplements to textbooks) and learning management systems (LMS). According to the Campus Computing Survey, about half of higher education institutions used an LMS in 2007 [11]. By 2011 not only did virtually all universities use an LMS [12], but only 7% had not standardized on a *single* institutional LMS [13]. From an institutional, teacher and student perspective the LMS is responsible for:

- Managing student credentials and class rosters
- Tracking entitlements to publisher content that is delivered by the LMS
- Recording student activity, task completion, and assessment results
- Analyzing and reporting results for the purposes grades and institutional research
- Delivering content and managing online communication with students
- Grading (via online assessments) and reporting grades

Most of these functions save time and money. Teachers like the LMS because it alleviates the tedium of grading, students like the "anywhere, anytime" access, administrators like them because they provide data and visibility, and publishers like the LMS because it provides a method to distribute, control and monetize their digitized intellectual property. As a result, the educational technology ecosystem found in higher education today is highly LMS-centric [14]. In recent years, many K-12 schools and jurisdictions have also invested in LMS technology. Other common educational technologies, including authoring tools, learning content management systems, assessment engines, and repositories, have been heavily influenced by the need to produce content that can be delivered via an LMS. In other words, the LMS is the dominant channel for formal learning, much as television once was for video [15].

This state of affairs has been changing for several years now as newer types of learning content have become more prevalent, including mobile apps, video lectures, online meetings, social learning, eBooks, games, and simulations. The typical LMS course contains didactic content and quizzes with pre-determined answers (e.g. multiple choice, matching and fill-in-the-blank questions), whereas these newer types of content tend to be more interactive and open ended in their assessment if student outcomes. User management and tracking results are still important in formal educational settings and for publishers' business models, but app stores and sites like YouTube are more natural delivery platforms for mobile and video content. "Learning content" is being replaced by "learning applications" that are hosted as mobile apps or as web applications in the cloud. Moreover, many of the most widely used and freely available courses (MOOCS) generate their own certificates of completion and are by their nature not tied to any one institution and therefore not to any institution's LMS.

3 Emerging Standards

As a consequence of these changes, the technical standards used by eLearning systems are being updated and revised to enable distributed systems to securely exchange data across the web [16]. This trend includes the IMS Global Learning Consortium's *Learning Tools Interoperability* (LTI) and *Learning Information Services* (LIS) specifications [17, 18] and the *Experience API* (also known as "Tin Can") produced by the U.S. Advanced Distributed Learning (ADL) initiative [19]. These standards enable applications to communicate without a central broker such as an LMS. They support interoperable reporting of assessment outcomes, course completions, and additional data relevant to learning experiences.

The capabilities offered by these emerging standards are critical for the adoption of the next generation of learning applications. For example, products such as ALEKS [20, 21], Autotutor [22, 23], Brainrush [24], Carnegie Learning [21, 25], Knewton [26], Wyang Outpost [16], and many others [27] are using embedded AI and, in some cases, game dynamics to create more effective and more engaging learning experiences. Students are now using these resources (and others such as the Kahn Academy and MOOCS) because they are either more effective or more available than traditional educational offerings. However, for these products to gain market acceptance they must be able to integrate with the ambient eLearning infrastructure. At some point schools, parents, and employers will want to see *evidence* of achievement. These systems will need to communicate results to institutional LMSs, online data repositories, and a variety of personal management apps running on the mobile devices of students, teachers, and parents.

4 New Product Categories

In addition to intelligent learning applications, many other new product categories are likely to emerge. Some will be engendered by societal requirements and others by advances in educational technology.

For example, students and teachers are increasingly associated with multiple institutions at the same time [28], and many of the more innovative learning technologies (including MOOCS and most of the systems listed earlier) are typically used outside standard classroom practice. This leads to requirements to track rosters, assignments, progress, and grades across multiple institutions and multiple online learning systems and to maintain a student's preferences in a "learner model" [29-31] that can be updated and exchanged by multiple adaptive learning systems. The natural evolution of the e-portfolio will be a personal learning record store that:

- Is securely controlled by the learner;
- Is portable as the learner works with multiple schools, teachers, tutors, and publishers over the years; and

- Contains the learner's preferences and his validated and certified formal and informal learning history.

This evolution would parallel the recent evolution of Electronic Health Records and, if implemented on a global scale, would spawn a plethora of products, ranging from tools to manage learning records to learning applications that take advantage of them to deliver more personalize, culturally relevant, and educational effective learning experiences.

Similarly, advances in cognitive science, computer science and information technology are also creating both requirements and affordances for new product categories. Just as the underlying technological components of expert systems have now found their way into hundreds of products from rice cookers to mobile phones, we anticipate that the AI components of today's intelligent tutoring systems will work their way into a wide range of learning products. The same is true for automated language understanding [32], automated grading [33], affect detection [34, 35], gesture and sketch recognition [36-38], and forms of social media that enable students to collaborate with each other and with adults (e.g. "granny tutors") [39].

Returning to the theme of standards, we observe that as learning products incorporate more intelligent features, they will generate and require significantly more data about learners, learning activities, and outcomes. Their commercial success will depend in part on their ability to create value by leveraging these data across multiple systems, jurisdictions, and stages of a life. Economically, it makes sense for learning systems to share their data rather than to hoard it, which is why standardized formats for data exchange are so important.

5 The IEEE Actionable Data Book Project

As pointed out above, standards help learning technologies integrate with existing infrastructure and processes. This means that innovations developed to meet the needs of a niche market – say one dominated by relatively low bandwidth cellular access, or one in which a culture demands different levels and types of privacy – can be used in other markets as well. Tools originally created for broader (or wealthier) markets would be more easily tailored for use elsewhere. As real-world example of a project where standards, new technologies, and unique requirements from a developing country have converged, we examine the IEEE *Actionable Data Book Project for STEM Education*, or more simply the IEEE ADB project [40].

The IEEE ADB project grew out of paper presented at the IEEE Global Humanitarian Technology Conference in 2011 that discussed a broadly applicable framework for building educational applications that combined field data collection and data visualization [41]. The requirements for the system presented in that paper came from the rice ecosystem management on the Indonesian island of Bali. In 2013, the suggestions in the paper were actualized in the IEEE ADB project. The goal of this one-year

R&D collaboration is to define and demonstrate an "actionable data book" consisting of a specialized eBook based on open standards that is tailored to support STEM education and supports learner accessibility and usage preferences. The requirements for the actionable data book are that it must be able to

- Use camera and GPS data from a learner's mobile platform
- Use measurements from local lab equipment
- Exchange results of learning interactions with cloud-based LMSs, analytics engines, and other applications
- Retrieve content from cloud-based sources (e.g. content repositories)
- Store and retrieve student history and preferences in the cloud

Operationally, the project is hosted by Industry Connections, an IEEE Standards Association program that facilitates the early exploration of potential interoperability solutions [42]. Participation is free and open to interested parties. The ADB project may continue past the initial year's charter, depending upon success.

Technologically, the project anticipates the global availability of a class of mobile devices comprising smart phones and connected tablets and explores the premise that those devices, in conjunction with a new content format, may provide the first truly global platform for connected learning. The format in question is EPUB 3 [43, 44], a new eBook format defined by the International Digital Publishing Forum [45].

EBooks have emerged as a mass-market commercial success within the past few years. To date, eBooks have only replicated the static content of printed books in a digital medium, but EPUB 3 introduces interactivity to eBooks by embracing JavaScript and the HTML5 standard for web page content. These characteristics make EPUB 3 an attractive foundation for a learning delivery platform. EPUB 3 offers a complete solution for portable, interactive, connected content, and it is relatively simple to map the requirements for an interactive learning activity onto baseline EPUB 3 capabilities. Since EPUB 3 is a general-purpose technology with broad appeal outside of the education industry, it is more likely than education-specific standards to be widely adopted, supported, and have a multi-decade life span.

Although most of the technology used by the IEEE ADB project was developed for commercial purposes in the developed world, its application to learning was originally inspired by the desire to enable students in remote locations to collect field data and share their data and culture with students in the United States. The first use case to which it will be applied is the construction of an enhanced, interactive guidebook for the new UNESCO World Heritage site on Bali [46-48].

The UNESCO site covers a significant geographical area encompassing 21 communities engaged in rice production and following traditional spiritual practices. This has resulted in an enormous challenge: How does one design an interactive guidebook that promotes the conservation and preservation of the site while meeting the needs of the people who live there, the international team developing and maintaining the site,

and tourists from all over the world with varying degrees of cultural sensitivity? The IEEE ADB project aims to help meet these requirements by developing onsite learning activities and guides that adapt to the local geography and culture as well as to those of the user's culture, while also providing remote connectivity to that allows students to vicariously experience the site from anywhere on the planet.

6 Conclusions

In developing economies new policies, institutions, and business models will transform the way education is delivered and managed. These efforts will take advantage of a wide range of innovative educational technologies and products to create local solutions that overcome geographical, social, and economic barriers using global infrastructure. It is easy to envision detailed student background information being securely available via the Internet and learning systems that compete with each other on the basis of how effectively they use this information.

Similarly, as more opportunities become available for students to access online video, daily lectures may become a thing of the past and expensive, classroom-based instruction may be needed less frequently or used differently, e.g. only for activities that require in-person group interactions or that use equipment not available in homes. Independent, trusted assessment services [49, 50] may allow students to progress in school based on their acquired competence, displacing today's cohort-based advancement schemes that measure progress by seat-time. The possibilities are unlimited and each educational jurisdiction will shape their solution by their specific needs and resources.

Data exchange standards and software interoperability standards are key to the flexible configuration of future systems, online services, and mobile applications. Standards-based products allow a school or a national or regional education agency to configure multiple products, including their current systems, into a stable working solution that fits local requirements and that allows new capabilities to be incorporated over time with minimal effort. The IEEE Actionable Data Book project is an example of a new model for learning delivery based on globally available, open standards that focuses on the realities of teaching and learning in the developing world.

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