The Importance of Software Standards in the Globalization of 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 expensive textbooks be replaced by open educational resources [2, 3]?
- What can children learn online on their own? How can the community help [51]?
- 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 innovations that would not otherwise be developed [10]. Typically, these solutions involve the novel reconfiguration of existing products along with some key technical innovation. The costs and risks involved in using existing products in novel ways are greatly reduced if the component systems conform to international data interoperability standards.

In this paper we argue that fruitful collaboration between developed and developing countries can take place in the area of standards development. We give a concrete example of how requirements from a project in Indonesia spurred innovation and how standards activities in the area of eBooks may provide solutions. First, we examine in general terms the technological landscape that is emerging in ed tech and the related efforts to define interoperability standards across these new product categories.

adfa, p. 1, 2011.

2 eLearning Infrastructure is Changing

Historically, commercial eLearning product sales in the United States have been 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 in the U.S. 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, in the U.S. and in the developed world generally, 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 the dominant means for delivery of video to the home [15].

The ed tech landscape is changing, however. The typical LMS-based course contains didactic content and quizzes with pre-determined answers (e.g. multiple choice, matching and fill-in-the-blank questions). In recent years, the emergence of new online and tablet-based learning products has caused institutions to look beyond the LMS: mobile learning apps, video lectures, online meetings, social learning, eBooks, games, and simulations. These newer types of educational content tend to be more interactive and open ended in their assessment of 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 New Product Categories

One result of the emergence of this variety of new online learning activities is the disaggregation of LMS functionality into multiple products categories (content management, roster management, scheduling, progress tracking, grade book, and so on). Advances in educational technology will drive the development of some new kinds of products, while others will be engendered by societal requirements. 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 trend leads to requirements to track rosters, assignments, progress, and grades across multiple institutions and multiple online learning systems.

One important example of a newly emerging product category is the Learning Record Store (LRS), an independent database where data about a student's learning activity can be registered by all of the online resources he uses. This data can then be reviewed by independent applications in additional product categories (e.g., intelligent tutors or learning analytics engines) to model the student and personalize his subsequent experience. An external data structure like the LRS could house the learner's history and 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 envisioned evolution of student records would parallel recent developments in 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].

It is the novel configuration of these new kinds of products, modifying or replacing some to meet local needs, that will enable developing countries to meet the many challenges of deploying effective elearning solutions: localization, limited bandwidth, costs, and so on.

4 Emerging Standards

Standards facilitate adoption of technology, especially institutional adoption, but they also stimulate innovation. By giving customers the greatest choice among plug-and-play competitors, interoperability standards create an avenue through which innovative new products can reach the market – replacing older technology and integrating with existing systems. Standards lower the barrier to entry, increase early adoption, and assure investors that new product ideas have market potential. 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.

There are currently no standards that would allow educational products of the sort described above to co-exist and share relevant data. Furthermore, 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.

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 online data repositories and a variety of personal management apps running on the mobile devices of students, teachers, and parents, as well as to the various institutional LMSs.

5 The IEEE Actionable Data Book Project

Early in 2013, parties interested in the future potential for eBooks in education organized the IEEE *Actionable Data Book (ADB) Project for STEM Education* [40]. The IEEE ADB project grew out of a 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 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

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 project has identified an initial technology demonstrator. The intent was to select a use case that was competitively neutral, of intrinsic appeal, and relevant to the developing world. The use case is an enhanced, interactive guidebook for the new UNESCO World Heritage Site on Bali [46-48]. The first edition of the guidebook was co-authored by Professor Julia Watson and Dr. Steve Lansing and endorsed by the Ministry of Culture and Education of the Republic of Indonesia in December 2012.

The UNESCO site covers a significant geographical area encompassing 21 communities engaged in rice production and following traditional spiritual practices. Coordinating all the stakeholders 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. The project will also support remote connectivity, allowing students an absorbing experience of the Bali site from anywhere on the planet.

The Guidebook offers visitors a comprehensive introduction to the four sites that comprise Bali's new World Heritage. The Balinese Subak System as a Manifestation of the Tri Hita Kirana Philosophy is a sacred landscape where the ongoing ritual cycles of centuries-old temples strive to harmonize society, nature and spirit. The question of how to structure visitor experiences needs to be carefully considered by the 21 communities in the sites. As the design of the project evolves, the connected learning platform being developed could, for example, be used to customize the learning experience based on the user's:

- Declared interests, background, culture, and so on. This data could be stored in the tablet or in a central database.
- Location at the moment, using the device's GPS capability
- Route taken across Bali, previous sites visited, and material already seen.

The UNESCO site is just an example of the affordances of the IEEE ADB. As noted above, the project is intended to support generic STEM education as well as learner accessibility and usage preferences. In this respect, the challenge for the IEEE ADB is to be regarded by the learning and teaching community as an improved platform that supports modern approaches to meaningful and transformative learning.

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 through 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.

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 its solution by its 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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