Hillsdale, NJ: Lawrence Erlbaum Associates.
Levin, H. M., & McEwan, P. J. (2000). *Cost-effectiveness analysis*. Thousand Oaks, CA: Sage.
Mayer, R. E. (Ed.). (2005). *The Cambridge handbook of multimedia learning*. New York: Cambridge University Press.
Mayer, R. E. (2011). Multimedia learning and games. In S. Tobias & J. D. Fletcher (Eds.), *Computer games and instruction* (pp. 281–305). Charlotte NC: Information Age Publishing.
Meehl, P. E. (1954). *Clinical vs. statistical prediction*. Minneapolis: University of Minnesota Press.
Minsky, M. L., & Papert, S. A. (1987). *Perceptrons: An introduction to computational geometry*. Cambridge, MA: MIT Press.
Phillips, J. J. (2003). *Return on investment in training and performance improvement programs (2nd edition)*. Oxford, UK: Butterworth-Heinemann.
Ross, J. A., Barkaoui, K., & Scott, G. (2007). Evaluations that consider the costs of educational programs. *American Journal of Evaluation, 28,* 477–492.
Schlais, H., & Wirth, D. (2007). ADL instructional objects for educational use. *ADL Newsletter for Educators and Educational Researchers; http://ymlp.com/zddizo* .
Scriven, M. (1975). Problems and prospects for individualization. In H. Talmage (Ed.), *Systems of individualized education* (pp. 199–210). Berkeley: McCutchan.
Sosa, G. W., Berger, D. E., Saw, A. T., & Mary, J. T., (2011). Effectiveness of computer-assisted instruction in statistics. A meta-analysis. *Review of Educational Research, 81,* 97–128.
Steinkuehler, C. A. (2011, April). Learning science: Computer games, simulations, and education—learning from and building on the 2011 National Research Council Report. Paper presented at the annual convention of the American Educational Research Association, New Orleans.
Tamim, R. M., Bernard, R. M., Borokowski, E., Abrami, P. C., & Schmid. R. F. (2011). What forty years of technology say about the impact of technology on learning: A second-order meta-analysis and validation study. *Review of Educational Research, 81,* 4–28.
Tobias, S. (1982). When do instructional methods make a difference? *Educational Researcher, 11*(4), 4–9.
Tobias, S., & Fletcher, J. D. (Eds.). (2011a). *Computer games and instruction*. Charlotte NC: Information Age Publishing.
Tobias, S., & Fletcher, J. D. (2011b). Computer games and instruction. The present, and future. In S. Tobias & J. D. Fletcher. (Eds.), *Computer games and instruction* (pp. 525–545). Charlotte NC: Information Age Publishing.
Tobias, S., Fletcher, J. D., Dai, D. Y, & Wind, A. (2011). Review of research on computer games. In S. Tobias & J. D. Fletcher (Eds.), *Computer games and instruction* (pp. 127–222). Charlotte NC: Information Age Publishing.
VanLehn, K. (in review). The two-sigma effect revisited: A meta-analysis of human tutoring and several types of computer tutoring.
Vinsonhaler, J. F., & Bass, R. K. (1972). A summary of ten major studies on CAI drill and practice. *Educational Technology, 12*(7), 29–32.
Wisher, R. A., & Khan, B. H. (Eds.). (2010). *Learning on demand: ADL and the future of e-learning*. Washington DC: Department of Defense.

E-learning Standards: SCORM and the Future of Interoperability

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E-Learning standards began to come on the scene in the late 1990s. SCORM is the most widely known and practiced example, but some would say that it has failed to yield the hoped-for results. The authors have been engaged in projects to determine the impact that SCORM has had, and this article presents the results of interviews with individuals who work with e-learning standards, either as developers, publishers of content, or educators. It describes the lessons garnered from the syntheses of the results of those interviews, summarizing the contributions and describing a direction for the future.

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Introduction

> *E-learning is not making an important, visible impact on the educational system of this country. Though its instructional value has been proven time after time, the high cost of the hardware and the lack of quality courseware is preventing interactive multimedia technology from becoming a market success.*

Despite being a very timely quote for 2011, this statement is from a 40-year-old abstract (Bunderson, 1971) in which "e-learning" was substituted here for "computer-aided instruction." Although it might be true that the educational impact of learning technologies has been less than anticipated, capabilities for delivery technologies now surpass even the wildest educators' dreams of yesteryear. Possibilities are primarily due not only to increased technological capabilities but also to:

- lower hardware and storage prices;
- favorable form factors; and
- file and data format standards for resources that ensure compatibility with tools and playability across platforms.

These technological advances notwithstanding, however, real advances in courseware have lagged far behind online entertainment products. Indeed, mass markets make content with high production values possible in the music, film, and video industries, with educational content in no way maintaining the same pace. One can easily argue that this is due primarily to the fact that today's classroom-based approach to education represents anything but a mass market, casting a shadow on the possibilities for a "knowledge economy," as advocated by Hodgins (2000). It is also possible that the means envisioned for making all this possible have not developed as Hodgins and others had thought possible.

This article is written with the assumption that a mass market for learning materials does potentially exist, but can only be developed when certain conditions are met. Specifically, learning materials must be locatable and be usable by learners.

In an effort to address that need, as well as to find ways to conceptualize the "mass of content used in the context of learning" (Hodgins, 2000, p. 1), or what we have described as "learning materials," Hodgins created the term "learning objects" in the early 1990s after watching his children playing with interchangeable Legos (Profetic, 2006). The term was later picked up in many quarters and fast became a central theme of efforts to make online learning generally available, such as within the IEEE Learning Technology Standards Committee (chaired by Hodgins), the IMS Global Learning Consortium, and the Advanced Distributed Learning (ADL) Initiative, among others.

An important outcome of the ensuing work of these and other efforts was the development of the Shareable Content Object Reference Model (SCORM). What began as a specification has become an international standard, given its adoption by the International Standards Organization as "Information technology—Sharable Content Object Reference Model (SCORM) 2004 3rd Edition" (ISO/IEC TR 29163-1:2009).

Anyone who uses any combination of electronics, automobiles, telephone, television, computers, and the Internet, and who also lives in a house or apartment, has at some point in their life been touched in some way by a host of standards. These are identified by a myriad combination of letters and numbers, all created by organizations and committees whose names are sometimes associated with the standards themselves: NTSC, PCI, XLR, RS-422, RS-232, RIAA, MPEG, JPEG, RJ-45, EIA, IEEE, HD DVD, BD, ANSI, ISO, SAE, TIA/EIA-568, SD, SDHC, HTTP, TCP/IP, IETF, ECMA, CD-DA, CD-ROM, CD-R, just to name some of these.

So, just as the acts of living, working, and taking leisure time are dependent upon standards, it seems reasonable to assume that standards also have a role to play in learning. This role should no doubt also play out in the production and delivery of learning materials (Bush, 2002) if that enterprise is to have the desired level of success.

What is the status of developments in this important area of e-learning standards? The purpose of this article is to provide a brief overview of recent developments specifically with respect to SCORM as well as insights regarding the future of the notion of e-learning standards in general. It will do this by providing an overview of findings gathered in work underway at Brigham Young University and by CS4Ed.

This brief overview is organized into sections that will include a summary of key points garnered from a synthesis of comments gathered in several interviews with about two dozen individuals from various organizations who have worked either in developing SCORM or in its implementation.

Elements of SCORM

SCORM can be summed up in its three main components: the Content Aggregation Model, the Run-Time Environment, and Sequencing.

Content Aggregation Model (Content Packaging)

The Content Aggregation Model includes specifications for the formatting of learning content and is the simplest and most industry-standard feature of SCORM. SCORM and Common Cartridge from IMS both reference the same specifications for packaging course content: the IMS Content Packaging Specification. This specification details how to organize resources in a zipped folder with a manifest, an XML document that describes the resources contained in the folder. SCORM and Common Cartridge both use the IEEE Learning Object Metadata Standard for describing learning content using XML, which is designed to aid in searching for and reusing learning content. The end result of creating content with these specifications is a learning object, whether a single lesson or an entire course, that can be imported into and used by a Learning Management System (LMS).

One advantage that Common Cartridge has over SCORM with respect to content packaging is that Common Cartridge uses Version 1.2 of the IMS Content Packaging Specification, which is more powerful than the older version included in SCORM. In particular, it includes better support for separating the manifest from the course content, allowing the content to be easily updated from a centralized, remote location without updating the manifest or redeploying the course.

While one key goal of a standard approach to content packaging is the ability to move content from one LMS to another, the results are at times less than desirable. For example, one institution investigated several learning management systems that claim to generate a conformant content manifest (Pullin, 2007). The researchers could not determine how to get the feature to work on one system. Several others seemed to work but "the structure and contents of the resulting packages were not the same" (Pullin, 2007, p. 5).

Run-Time Environment

The Run-Time Environment (RTE) defines the communication between the course and the LMS and can be employed to collect a wealth of data. Whereas other standards for e-learning content may only gather responses to assessment questions, the RTE can also gather data on how long the user spends on a particular activity, whether or not it has been completed, and if the course requirements have been satisfied. Unfortunately, not all LMSs have sufficiently robust data-reporting capabilities to take advantage of the Run-Time Environment's potential. Complex use of the RTE in a course might be technically SCORM conformant but not truly interoperable across all learning management systems.

Sequencing

Sequencing was included in SCORM 2004 in order to increase adaptability to learners. Specifically, sequencing is designed to facilitate reducing a course to multiple, smaller learning objects that can be sequenced, rather than having to create the entire course as a single learning object that would have internal sequencing only. In this way, sequencing could allow learning content to adjust to the learner, such as delivering remedial content to low-scoring learners.

As one of the youngest and least mature parts of the SCORM standard, however, even the SCORM advocates we interviewed noted that the implementation of sequencing can become complicated to the point that it is no longer cost-effective. Indeed, because of the varying support for and the complexity of these more advanced features of SCORM, many believe that SCORM inherently requires a lot of "tinkering"—but fans are quick to point out that SCORM's advanced features need not be used extensively to create SCORM conformant content. SCORM's Content Aggregation Model can be used alone to create un-sequenced courses.

SCORM Compared to Common Cartridge

As challenging as the implementation of SCORM's more complex features can be, those features offer capabilities not found in other formats. These are most easily seen in comparison to another popular approach for creating and distributing e-learning content, Common Cartridge (CC) from IMS. Where the Run-Time Environment collects learner data, such as duration and completion times as well as assessment responses and scores, Common Cartridge focuses only on the latter. In addition, features like bookmarking and self-paced, sequenced content are unique to SCORM.

Lacking SCORM's Sequencing and Run-Time Environment, CC has developed into a simpler format that works "out-of-the-box," which requires less development time with more focus on the learning content. The fact that the specifications on which the content packaging in CC is based are more up-date makes this approach more modular than SCORM. CC allows integration with a greater variety of media and the ability to link to learning resources hosted on a remote server. This last feature allows easy, centralized updating of content without having to redeploy the course. In contrast, SCORM is less current, and although it offers unique data-collection and sequencing capabilities, those extra features can be prohibitively complex in terms of both development time and varying support from learning management systems.

The Potential of SCORM

The more advanced features of SCORM 2004, such as the Run-Time Environment and Sequencing, tantalize with the promise of advanced data collection and the potential to order course content to fit the needs of individual learners. Unfortunately, the vision of these features too often outstrips technical implementation, leaving educators to endure the punishment of Tantalus, neither able to taste the fruit nor drink the water that are both seemingly within reach. The complexity of certain elements of SCORM (RTE and Sequencing) pose a challenge to interoperability and cost-effectiveness, and even the simpler Content Aggregation Model has its challenges. It is described as serviceable by some, outdated according to others, and deemed "not optimal" according to still others (Pullin, 2007, p. 5).

To summarize the general findings, SCORM is a powerful standard—with some individuals stating that it has a lot of room to mature for the future, while others use the expression "past its peak." Described by some as the best fit for self-paced, single-learner courses, technical experts remarked that the standard is surprisingly flexible and could be adapted to any number of uses.

From the Complete SCORM to Just Interoperability

SCORM set out to enable learning materials to be accessible, adaptable, affordable, durable, interoperable, and reusable. Despite some measure of success in that endeavor, it appears that two specific issues have as of yet not been adequately addressed. First is the issue of granularity of SCOs. Another development missed in the initial vision is the fact that much learning takes place in many settings other than through a CBT model.

With respect to the first issue, this article's first author raised questions in July 2000 with the initial editor of the SCORM specification regarding the granularity of SCOs. The response received was that the Course Structure Format from AICC was guiding SCORM at the time (Dodds, 2000), an issue that seems to now be taking its toll. The result has been the creation of huge numbers of single-SCO courses that rely on the LMS for sequencing, which has reduced reusability.

Relative to moving beyond a CBT-based, e-learning model, educators don't talk about "blackboard learning," "PowerPoint learning," or "overhead projector learning." One has to raise the question that whatever is done with learning management systems must account for learning of all types. This would include lectures, online learning, team projects and group work, classroom experiences, simulations, reading textbooks, "Googling," etc. With respect to assessment of learning outcomes, such a system would take into account not only teacher evaluations and scores awarded by the LMS, but also self-evaluation and peer evaluation.

Finally, despite its adoption as an international standard, SCORM has seemingly diminished in importance, while at the same time Common Cartridge has garnered increased attention and implementation. In addition, work is underway by LETSI (International Federation for Learning, Education, and Training Systems Interoperability), the stated purpose of which is "accelerating innovation in e-learning "(LETSI, 2011).

Given these challenges and the enticing vision that remains, one possibility would be to reduce the scope of the goals that were envisioned at the outset. Based on the interviews and experience of the authors, it seems that the primary issue on which no compromise is possible is that of interoperability, which happens to be the watchword of LETSI, as it pursues its service-based approaches to addressing the problems raised here.

The Future of Interoperability

Interoperability and Context

Responses from the long-term study of consumer and supplier experience that CS4Ed has conducted convincingly showed that "interoperability" signifies mostly subjective judgments about relative differences, rather than absolute differences of a readily measurable property of digital content or software. This is not to say that relative differences in something called "interoperability" are not real or that there are not at least informal measures of those differences.

Claims of interoperability too often can be both true and false, however, because they are made without the necessary context that is provided by the question, "From which perspective and on which dimension?" The answer, of course, depends on points of view and measures associated with them. Stockbrokers and pensioners view markets differently and have different metrics of performance; so might tool developers, content providers, educators, and administrators.

Trying to correct or refine the meaning of interoperability would be a fool's errand. The term is popular, but, alas, it is too corrupt to be saved. Instead, perhaps it would be helpful to consider separate viewpoints from which interoperability commonly is judged and measures by which judgments might be compared—in the hope of arriving at predictions for the future of SCORM.

Viewpoints and Metrics

End-users such as faculty members or instructional designers view the specific benefits of technical interoperability in terms of convenience or ease of use. Their sense of the time or effort that is required (or saved) for tasks other than performing an everyday function or realizing an educational goal determines their judgment of *technical* interoperability. If something is difficult to use or doesn't 'fit the hand,' then it isn't interoperable. In other words, interoperability depends on usability.

System developers also apply their sense of the time, labor, or resources expended or saved to perform a task or produce a result in making judgments of interoperability. Training, support, and the availability of colleagues in a community of practice also improve these judgments. The everyday functions and technical outcomes on which developers base those judgments depend, however, on the technology being visible and the level of integration that is possible. In other words, interoperability depends on integratability.

Interoperability, as assessed by managers and administrators, depends on the immediate and lifetime costs of producing or acquiring and installing and maintaining a capability. This assessment includes the collateral costs of use, such as the degree of difficulty and level of expertise that is required to obtain results using: (1) the capability, (2) the enhancement of marketplace choice, and (3) the competitive advantage it provides, as well as the responsiveness to opportunity it imparts. In other words, interoperability depends on (organizational) habitability, or the ability to live with the results of decisions made as to tools selected and content acquired.

Compliance and Interoperability

Current tests of compliance with standards and plugfest demonstrations of interoperability among implementations are indirect metrics of interoperability because at this stage of the evolution of the underlying standards they are general and incomplete. They provide all-or-none results, and they do not sufficiently differentiate among end-user, developer, and managerial viewpoints and metrics. Thus, successful results have limited, if any, value as predictors of interoperability in use. Tests whose outcome provides more information about usability, integratability, and habitability provide more authentic metrics and are necessary to hazard such predictions and estimates of time, cost, and risk.

More sophisticated metrics of interoperability will emerge as adoption and use over time increase the sophistication of expectations of interoperability. These metrics are just beginning to be identified and inform the process of standards development and maintenance. As this process continues, what 'plug and play' means will become more complex, more concrete, and thus more testable. As this process unfolds, it will become even more apparent that interoperability is not the "pixie dust" that makes usability, integratability, and habitability automatic.

It is important to note that educational technology is not the first field to discover that simple-minded plug and play is an illusion. Albert Einstein said that "Everything should be made as simple as possible, but not one bit simpler." Alfred North Whitehead said that people should "Seek simplicity, and distrust it."

Standards and Reference Models

Although SCORM and standards from IMS, SIF, W3C, and other sources are in fairly wide use, the maintenance and evolution of interoperability standards and their associated documentation, compliance tests, reference implementations, and infrastructure have been limited. They have not yet evolved in response to the cloud/app/mobile technology warp and associated pedagogical changes that have occurred recently. It is unlikely they will have continuing tactical impact on training or education in their present form. Improving them and maintaining them will require substantial organizational support.

The Standards Movement

To have continuing strategic impact, standards organizations will need to re-establish the more collaborative approach to development by which the original SCORM was produced. Industry-wide interoperability is too complex and costly a property to be provided by a single organization or a single approach to development.

Authentic Goals and Metrics

The objectives of these organizations will change from perfect and comprehensive interoperability to practical and contextually specific interoperability.

The underlying technologies for cloud hosting for multimedia content and software as a service and applications for providing and using them on multiple devices have become interoperable. In response, educational interoperability is evolving from that between relatively large components such as LMSs and courses to smaller, interchangeable tools and content, and interactions that connect and communicate flexibly. The absolute interoperability of a single app or learning object will be difficult, if not impossible, to test. Instead, testing is likely to become experimentation; lab trials with sample inputs that generate detailed results.

The Future of E-learning Standards

Although computer and Internet technologies have become more sophisticated and less expensive, technological improvements have not translated into the impact on e-learning that educators have long envisioned. Impact on the growth of the e-learning market and learning outcomes remains hampered by problems of interoperability. SCORM, for example, offers unique features that allow more detailed data collection and content adapted to individual learners—the potential for a course to be more like a personal tutor instead of a textbook. Complexity of implementation and spotty support across systems, however, limit SCORM's market impact and use in innovative learning tools.

Currently, content that is labeled conformant to the SCORM standard might not be practically interoperable; it can be costly to develop and to migrate from one system to another. The content may fulfill the technical specifications of SCORM and yet not reap the benefits of interoperability. Looking to the future of e-learning, whether that future involves continued development of SCORM, Common Cartridge, or the creation of new standards, the key to greater market impact and innovation is creating standards with an eye to an interoperability based on usability, integratability, and habitability. □

References

Bunderson, C. V. (1971). Markets and models for large-scale courseware development. ED071453.

Bush, M. D. (2002). Connecting instructional design to international standards for content reusability. *Educational Technology, 42*(6), 5–13; *http://arclite.byu.edu/digital/edtechscorm.htm* .

Dodds, P. (2000, July 14). *Personal e-mail exchange*.

Hodgins, W. (2000). The future of learning objects. In D. Wiley (Ed.), *The instructional use of learning objects; http://www.reusability.org/read/chapters/hodgins.doc* .

LETSI. (2011). LETSI Website; *http://www.letsi.org/* .

Profetic. (2006, March 1). Interview with M. H. Wayne Hodgins; *http://www.profetic.org/IMG/pdf/0602-wayne hodgins2.pdf* .

Pullin, M. (2007). IMS content packaging research report. Texas Center for Digital Knowledge, University of North Texas; *http://thecblor.unt.edu/files/IMSCP-Report-2.pdf* .