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USING OPEN-SOURCE TOOLS TO DESIGN AND DEVELOP THE ONLINE COMPONENT OF A BLENDED-LEARNING, INSTRUCTOR-LED COURSE

Ioan G. Ionas, Matthew A. Easter, & William H. Miller, *University of Missouri—Columbia*
Gayla M. Neumeyer, *University of Missouri Research Reactor*

In the design case presented, an online component was designed for an existing introductory energy course targeted at providing pathways to employment in the utility industry. The online component included testing modules, scenario based assessments, and reading materials. The existing pencil and paper course was now to be an instructor-led, blended-learning course. While technologies have advanced in recent years, the question of how to blend computer technology with sound instructional design practices is very much alive and may be even more important when targeting content portability. This paper explores the challenges faced when attempting to use open-source applications in the design, development, and deployment of the online component of this course when primary objectives are outreach, access, portability of content, and ease of future updates.

Ioan Gelu Ionas is a Research Assistant Professor at the University of Missouri. He received his Ph.D. in Information Science and Learning Technologies from the University of Missouri—Columbia. He also holds a BS in Mechanical Engineering, an MBA degree from the University of Missouri—Columbia as well as a Ph.D. in Management from the University of Sibiu, Romania. Gelu has taught for more than 10 years in engineering, business and education. His research interests focus on instructional design, causal reasoning and understanding, online learning, and cross-disciplinary research at the confluence of learning, cognition and technology.

Matthew Easter is an associate research professor at the University of Missouri. He recently earned his doctorate in Educational Psychology from the University of Missouri. His research includes investigating how conceptual change theories relate to cognitive theories of motivation. He also assists in the development and study of online learning environments in the College of Engineering at the University of Missouri.

William H. Miller is Professor Emeritus in the Nuclear Science and Engineering Institute at the University of Missouri-Columbia, where he has taught graduate nuclear engineering for 35 years. He is the author of over 125 technical papers and has made over 1000 presentations to the public on issues concerning energy, the environment, radiation and nuclear power. He is a registered Professional Engineering in the State of Missouri and a Certified Health Physicist. His Ph.D. was in Nuclear Engineering from the University of Missouri-Columbia. He is currently a Research Scientist at the Missouri University Research Reactor.

Gayla M. Neumeyer is manager of energy industry educational program development with the MU Research Reactor, and the MU Energy Systems and Resources Program. She is a founding member and Secretary of the Missouri Energy Workforce Consortium (an affiliate of the national Center for Energy Workforce Development)

CONTEXT

The aging workforce has become a major problem in the utility industry (Ashworth, 2006), with reports estimating that 30 to 40 percent of current employees will reach retirement age in the next few years (e.g., Ashworth, 2006; Farrell, 2011; Sen, 2012). In response to the coming workforce shortage, a non-profit consortium of electrical, natural gas, and nuclear utilities and their association, the Center for Energy Workforce Development (CEWD) (http://www.cewd.org/) was formed to help utilities work together to develop solutions. The Energy Industry Fundamentals (EIF) course is part of CEWD's efforts to provide pathways towards employment in the utility industry through education. CEWD's initial efforts in developing this course focused on designing and developing the skill and knowledge content for entry level technical occupations in a paper-based format, as well as awarding successful students the opportunity to receive a American National Standards Institute certificate for successful completion of the EIF.

THE DESIGN PROBLEM

The EIF course provides a broad understanding of the electrical and natural gas utility industry, and the energy generation, transmission, and distribution infrastructure. It includes business models, regulations, types of energy and their conversion to usable energy (primarily focusing on electric power), how generated electricity is transmitted and distributed to the point of end use, and emerging generation technologies. Inherent in the curriculum is a focus on providing background on education and training pathways to careers in the energy industry.

During the process of developing and accrediting[1] the course, the CEWD became interested in extending the learning experience beyond a traditional paper-based format. Their interest was twofold: on one side was their interest in improving retention and problem-solving skills by situating the knowledge content of the course in the context of the various job-related activities learners might encounter in the utility industry. On the other side, they were interested in bringing the course materials (content, contextual information and tests) online in a format suitable for a blended learning model.

The main reasons and objectives set forth by CEWD for their interest in offering the EIF course online and in a blended-learning format were: outreach, ease of access, portability of content, and ease of future updates. CEWD's primary interest in establishing—and subsequent deployment of—the EIF curriculum was to support participants from across the United States with the background knowledge to increase success in passing pre-employment exams, which are used extensively by most utility employers as an employment screening strategy. Thus, CEWD's interest was for any interested entity (e.g., school, utility company) to be able to offer this course to potential and current employees, either from a central location or by using their own information technology infrastructure. With aspects of the utility industry (e.g., regulations) frequently changing, the course content needed to be easy to update and redistribute.

Considering our prior experience in developing web-based educational solutions for the energy industry (Miller et al., 2007; Miller et al., 2009; Schmidt, Easter, Jonassen, Miller, & Ionas, 2008), the University of Missouri—Columbia partnered with the CEWD to design, develop, and help deploy CEWD's goals for the re-formatted curriculum. Through funding under a US Department of Labor ARRA State Energy Sector Partnership and Training Grant, the University of Missouri—Columbia team's efforts included the development of a contextualization layer, aimed at situating the knowledge content of the course in the context of job-related activities, as well as bringing the updated version of the course online.

THE DESIGN DECISION

The online version of the course that we designed utilized the existing paper-based course in two ways. First, we converted all the existing theoretical content and reading materials to an online format. Second, we created a testing module that incorporated the existing testing materials in an online format. Besides these efforts, we also created the contextualization layer in hopes of improving student problem solving skills and overall learning.

We incorporated this contextualization layer in two ways. First, we included scenarios within the existing reading materials. These learning scenarios are presented in contexts that were relevant to the preceding readings, to encourage students to apply what they have just read to solve a problem. Second, we included another set of scenarios that are presented after all of the module or chapter's readings. As with the learning scenarios, these review scenarios are presented in contexts relevant to the reading. Students are also asked to solve problems in the review scenarios, and their efforts to do so are less guided than for the learning scenarios.

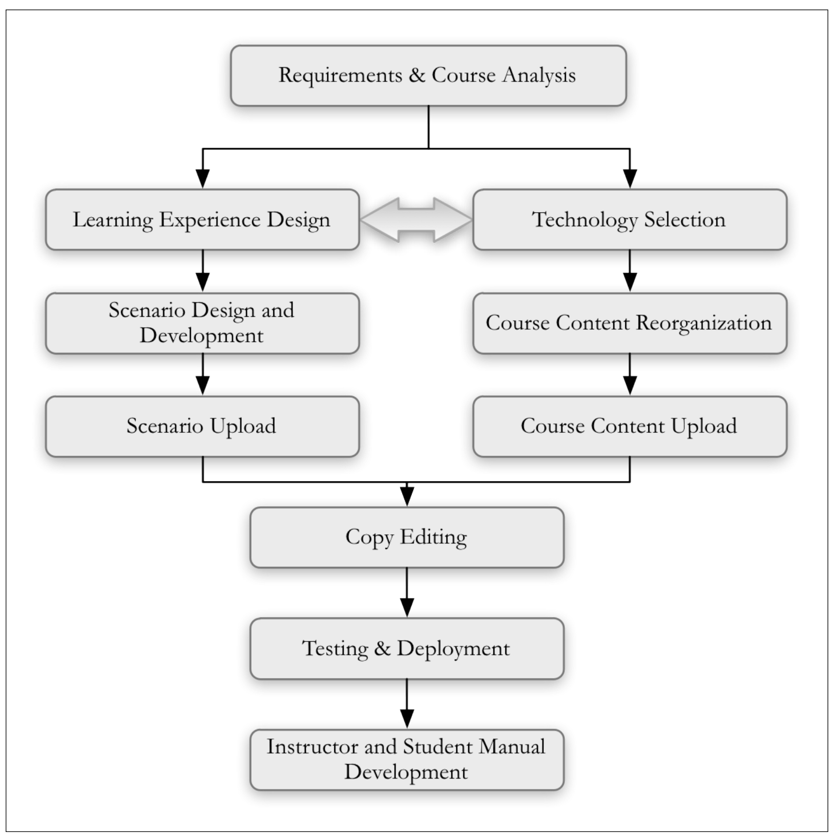

FIGURE 1. Overview of the design and development process.

THE DESIGN PROCESS

Based on our collaborations with the CEWD, we defined the following targets for the University of Missouri—Columbia team's efforts:

1. Design and develop a learning experience to provide a contextualization layer to the course content
2. Design and develop a solution for online course content portability between a variety of learning management systems and information technology platforms.
3. Select a learning management platform and hosting solution for the initial implementation of the online course.
4. Generate the electronic version of the course content and contextualization solution, using the chosen learning management platform and learning content portability standards.
5. Develop documentation for instructors and students for the use of the chosen learning management platform.

The main stages of the design, development, and implementation process are shown in Figure 1. The first step in the process was to analyze the requirements and the existing content to understand the context and define the learning experience that would meet these requirements. During the initial process, we began researching the various content portability standards and information technologies that would support the objectives set forth for this implementation. We continue scanning for new information technology advancements for their potential applicability.

Once the foundations were in place, we began an iterative design and development process. This included learning experience design, artifact design and development, porting existing content online, copyediting, testing, implementation, and the development of both student and teacher manuals for using the web-based environment. The various sections in this paper present this design and development process, together with the issues encountered, the solutions found, and the decisions made to best support learning.

Designing the Learning Experience

Our efforts to define the best learning experience began with looking at the wider area of situated cognition and situated learning (Henning, 2004). Further analysis focused our options on Case-Based Learning (CBL). The learning experience design and development process is presented in Figure 2.

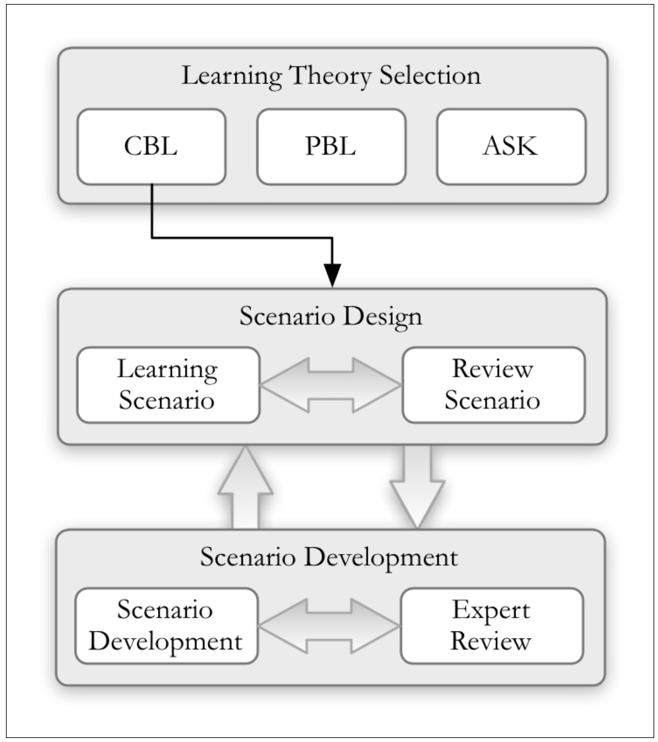

FIGURE 2. Learning experience design process.

The Learning Theory

Question	Which method for learning experience contextualization would fit our needs?
Objectives	Provide context Engage learners Improve retention and performance
Decision	Case-based reasoning Goal-based scenarios
Tradeoffs	Complex, iterative, and lengthy design and development process Possibility of cognitive overload Need for subject matter experts Challenging document management

Research on situated cognition and situated learning shows that when people learn and reason in context they tend to perform better in problem solving tasks and have better retention of the content (Henning, 2004). In this respect, scenarios are tools instructors can use to contextualize a learner's experience to a desired domain or area. The scenario presents the learner with a story, causal in nature, which asks the learner to predict an outcome or infer a result. According to Jonassen (2011), a scenario is hypothetical (represents a possible situation), selective (represents one possible state of complex, interdependent, and dynamic events), bounded (limits the number of possible states, events, actions, and consequences), connected (causality is present to link related elements and events), and assessable (can be judged).

For our purposes with the EIF course content, the CBL approach was chosen to provide context for learning (Shank, Fano, Bell, & Jona, 1993). Goal-based scenarios are used as instructional tools since the contextualization they provide promotes the best and most connected learning as the learner actively pursues a meaningful problem-solving goal that leverages contextualized knowledge. The role-playing aspect of using scenarios supports understanding and learning the circumstances where the new knowledge is useful (as compared to when the material is presented without the role-playing component) (Kolodner, Ownesby, & Guzdial, 2004). Questions within these narratives present learners with prompts to devise arguments to support their own selected stances about issues and topics, as well as to evaluate the arguments of others. As Jonassen and Kim (2009) point out, argumentation can help support problem solving skills and engage learners in deeper, more meaningful forms of learning.

The Course Delivery Format

Decision	Instructor-led, blended learning format, per requirements

The blended learning format attempts to provide the most effective and efficient instruction experience by combining delivery methods. The most common approach is to combine face-to-face instruction with online learning, both live and self-paced. This approach multiplies the ways people learn, which reportedly increases understanding and retention(Dziuban, Hartman, Juge, Moskak, & Sorg, 2005). When designing instruction for a blended-learning approach, two major challenges are encountered:

> **Management of instructional complexity.** With the combination of various delivery methods, it becomes increasingly more difficult for the designer, instructor, and ultimately the learner to manage the various sources from which the content comes.
>
> **Uniform learning experience.** As the different media work together, designing and delivering a uniform learning experience that combines them all becomes increasingly more difficult.

A major advantage of the blended learning format is its ability to improve effectiveness by providing the best delivery environment for each "learning object." It also provides learners with alternative ways of learning, thus offering them the ability to choose the medium that works best for them. That is, it provides ways to personalize instruction and learning.

Another way to view blended learning is that it allows for a variety of digital learning technologies to be integrated in a face-to-face instruction or learning experience (Bonk & Graham, 2005).

Usually, for blended learning courses, the mixture of online and face-to-face activities has no predefined format. The instructor decides which activities will take place online and which will take place face-to-face. For the Energy Industry Fundamentals class, we recommend the instructors use the online materials for teaching the knowledge content, administering tests, and for activities covering the tasks included in the contextualization component that we developed. For face-to-face activities, we recommend that instructors include the tasks related to practical applications (e.g., laboratory work), as well as to conduct review sessions over both the material and contextualization scenarios (see next sections for details). Because many of the instructors who would potentially teach the EIF course were, or still are, practicing professionals in the utility industry, we also encourage them to use face-to-face meetings to share their own experiences and lessons they learned from practice.

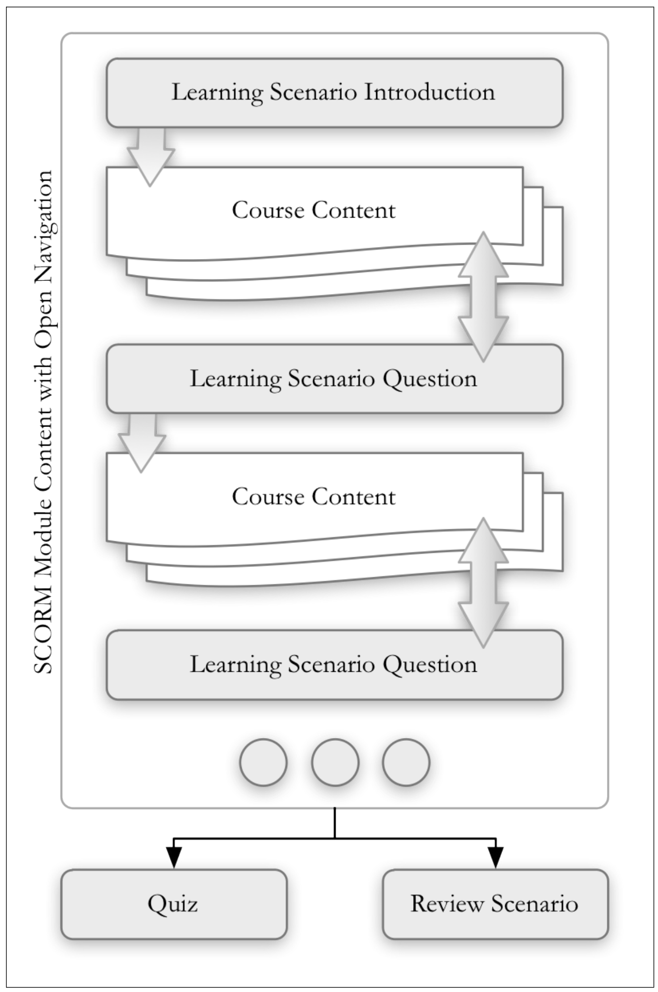

FIGURE 3. A typical learning path.

The Learning Experience

Following an iterative design process, we decided upon a two-step design of the learning experience, which provides contextualization by introducing two scenarios for each module or coherent unit of instruction (i.e., chapter).

The first scenario—the *learning scenario*—is used alongside the text to provide context while learning the content. This scenario is introduced at the beginning of the module and continues throughout the content. It includes context setting, some theoretical background as appropriate, and questions. The questions ask learners to provide an argument for a decision that has already been presented to them in the scenario. They are designed to help learners reason about a situation as they read the content. While working on the learning scenario, learners can consult the course content to review the material in order to understand the context and answer the questions.

The second scenario—the *review scenario*—was designed to help learners review the material after they have completed the module or chapter and is intended to provide another opportunity to apply the knowledge they accumulated. It has a higher level of difficulty as compared to the "learning scenario." In this case, the leaner is asked to both make a decision from a constrained list of options presented as multiple choice questions and provide an argument to support that decision. Figure 3 shows the typical learning path designed for a course module or chapter.

The use of a two-step approach in designing the learning experience required differentiating how the two scenarios would be delivered. As mentioned previously, the learning scenario, embedded within the theoretical content, requires an open content navigation model that allows learners to review the content, understand the context, and answer the questions within the module. The review scenario is designed to be self-contained, outside of the main module content. The theoretical design advises the use of immediate feedback to learners' answers for both types of scenarios, as well as instructor feedback to open-ended questions.

The multiple-choice answers, where appropriate, are evaluated upon submission, while the open-ended answers are sent to the instructor for evaluation, optional grading, and feedback. Additionally, for both scenario types, the initial design proposed an expert answer be provided to the learners upon submission of an answer. This expert answer would offer students immediate feedback they could to evaluate their own answers. While the designed learning experience is pedagogically sound, choices and technological limitations would ultimately alter this design.

Developing the Contextualization Layer

Once we decided upon which learning experience was more appropriate for contextualizing learning to job-specific

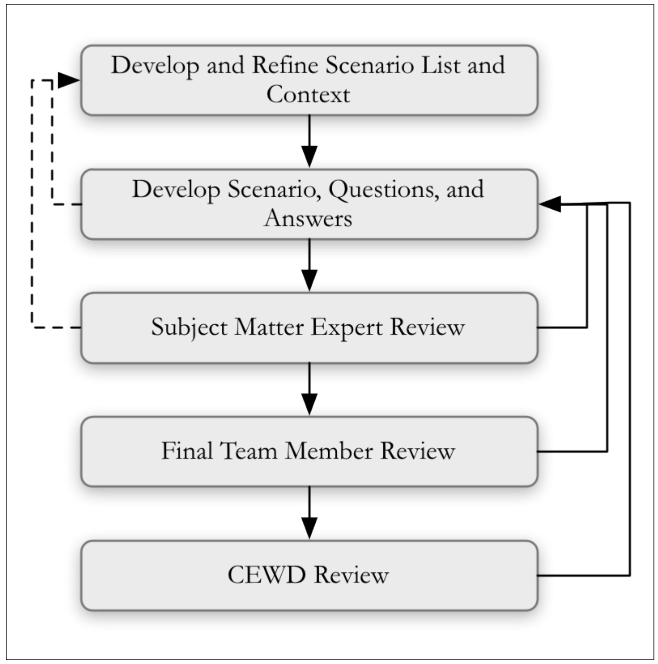

FIGURE 4. The scenario development process.

activities, our next step was to develop a process for designing and developing the scenarios. To provide the expertise regarding utility industry occupational situations, we worked with a subject matter expert (SME), whose role was to help with the scenario planning, to connect the theoretical content to job-specific tasks, and to review the content we generated for veracity.

The scenario development process is presented in Figure 4. First, with the help of the SME, we created a list of topics for each module or chapter. These topics were designed to cover as much theoretical material as possible. For each chapter we designed the scenarios so that they related to each other, with the review scenario continuing, whenever possible, the learning scenario. For consistency, we extended this relationship to scenarios in other modules, whenever possible.

Once these topics were generated, we began the scenario and question development process. Each scenario includes an introductory section aimed at setting the stage and questions. Each question is accompanied by a written scenario section, which builds upon the introduction and the previous question(s). The scenarios were written as dialogues between characters specifically created to represent the various players in a specific job environment in the utility industry. We started building our pool of characters with the first scenario and, to maintain consistency, tried to reuse these characters in the scenarios designed for subsequent modules or chapters. For each scenario, we developed questions accompanied by the appropriate answers.

The scenarios for each module were developed over a number of iterations. One of our team members wrote the initial scenario, which was later refined with the SME's help. A different member of our team reviewed the scenario in its final form, looking for inconsistencies and appropriate technical jargon use. Our collaborators at CEWD performed a final review.

While this entire process may sound simple and straightforward, it was not. Overall, the process was long and tedious, with frequent unexpected issues arising (e.g., writer's block in scenario development). Some of the topics we originally considered for scenarios proved not to be appropriate for the content or were too difficult to understand. Therefore, during this process some of the topics were changed to better meet the requirements of the knowledge content they were designed to illustrate.

This situation was further compounded by difficulties in the scenario writing process. To limit cognitive overload on students, we tried to keep the scenarios as short as possible. As we found out, some of the topics we attempted to develop proved to be too complex for a short scenario and therefore were not used. In addition, there were instances when the CEWD's reviewer suggested changes to the scenario, which had to be vetted again by our SME and technical reviewers.

Learning Content Portability Standards and Information Technology

With portability as one of the main objectives driving our efforts, we began analyzing the standards that would allow us to bring the content online in such a way that it could be moved between different learning management systems (LMS). As shown in Figure 5, we looked at the standards that we could use to develop the content to guide our search for deployment options, learning management system applications, and content development tools.

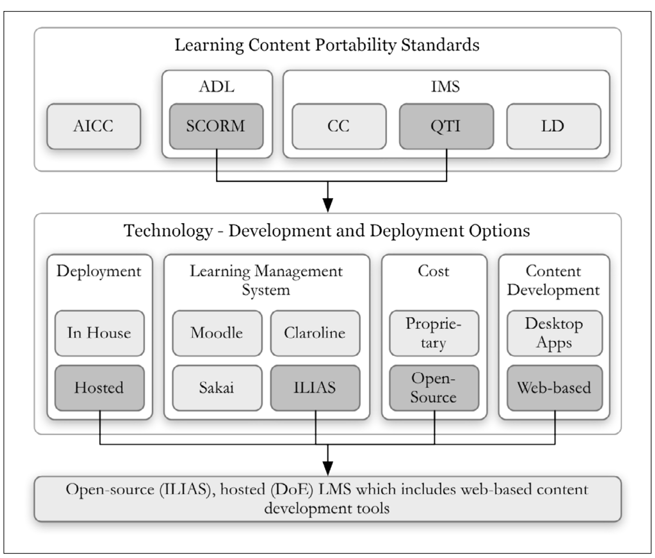

FIGURE 5. Learning content portability standards and technology selection.

Learning Content Portability Standards

Question	Which learning content portability standard(s) would fit our needs?
Objectives	Ability to move content between various delivery platforms Preserve the learning experience Permit feedback Allow instructor to assess open-ended questions
Decision	Sharable Content Object Reference Model (SCORM) Question and Test Interoperability (QTI) Standard
Tradeoffs	Need to overcome SCORM standard limitations Deviations from SCORM tenets Use of multiple standards to accommodate design and delivery needs Social presence not portable between environments

Several standards for learning content portability are available and in use today. For this work, we analyzed the following standards: Aviation Industry Computer-Based Training Committee (AICC), the Sharable Content Object Reference Model (SCORM), the IMS Global Learning Consortium Common Cartridge (CC), and the IMS Global Learning Consortium Question and Test Interoperability (QTI) standard.

AICC. Aviation Industry Computer-Based Training Committee (AICC) is the oldest standard we reviewed. Developed by the aviation industry in 1993, AICC has not evolved much since its creation but has served as a precursor of the newer SCORM standard. AICC standard's main disadvantage is the lack of ability to ensure that metadata[2] associated with the content is portable (Ostyn, 2007).

SCORM. The Sharable Content Object Reference Model (SCORM) was developed and is maintained by the Advanced Distributed Learning Initiative (ADL). The fundamental objectives of the SCORM standard are portability, interoperability, reusability, accessibility, and durability. It is a mature standard and is arguably the most widespread standard used today for content portability. One of the major drawbacks of SCORM is that it does not allow the LMS to access the internal components of the object[3] ("SCORM," n.d.). This means that feedback from outside the Sharable Content Object (for example, instructor feedback) is difficult—if not impossible—to implement

IMS Common Cartridge. Developed by the IMS Global Learning Consortium, Common Cartridge (CC) is a more recent initiative, which expands the reach and interoperability of the existing standards. Notably, CC is better positioned to support a blended learning approach, provides access to a greater choice of content, has greater assessment options, and increases flexibility, sharing, and reuse. It also allows the host learning management system access to the internal components of the cartridge, as opposed to the other competing standards ("Common Cartridge Working Group," n.d.). This approaches some of SCORM's limitations by, for example, allowing feedback to be provided to learners or making possible to include discussion threads inside the cartridge.

IMS QTI. Also developed by the IMS Global Learning Consortium, the Question and Test Interoperability (QTI) specifications are a mature set of standards, implemented by the majority of learning management system applications. QTI provides specifications based on the XML language for describing questions and tests to allow interoperability between various assessment systems ("IMS Question & Test Interoperability Specification," n.d.).

AICC aside, an analysis of the capabilities of several learning management systems showed that while the IMS Common Cartridge standard could serve us better, in the interest of interchangeability, the SCORM standard is still dominant. While SCORM allows for testing items to be included in the content, its capabilities are relatively limited. Nevertheless, the IMS QTI standard is widespread, which allowed us to overcome some of SCORM's limitations by using it to implement the tests and the review scenarios. To better understand the scope and purpose of the SCORM standard, a brief overview is presented below.

Brief Overview of the SCORM Standard

The fundamental objectives of the SCORM standard are portability, interoperability, reusability, accessibility, and durability. In SCORM terms, portability means that the content should work with no changes or adaptation in different online and offline environments. Interoperability specifies that the same content should work in the same way anywhere it is deployed. Reusability requires the ability to combine the modules in different ways. Accessibility requires cataloging metadata to be associated with the content to make it easy for both learners and developers to find the appropriate content in a content repository. Finally, durability dictates that the content should only last as long as it is relevant, but long enough to recover or amortize cost.

Currently, there are two major specifications of the standard. Version 1.2, released in 2001, was originally developed by the U.S. Department of Defense and designed to overcome the limitations of the AICC standard. While better than AICC, the SCORM standard still has a multitude of shortcomings and ambiguities, some of which were addressed in the newer version of the standard which was first developed in 2004, and is now in its 4th edition (http://www.adlnet.org/).

The basic concept behind SCORM is the Content Aggregation Model, which defines the ways to identify and describe learning resources, how to aggregate them into a course and how to move them between host environments. A Sharable Content Object (SCO) is composed of web content designed to be compatible with any browser. This content should be able to run both in online and offline environment (e.g., on a compact disk (CD)) without any supplementary requirements other than a web browser. What SCORM does not specify is how to design the content (pedagogy), the look and feel (interface), what to do with the tracking data, and what should be the granularity of the SCOs and other content objects.

The more significant issues with the current SCORM standard are:

1. The need for extensive metadata to catalogue the SCOs.
2. The need for context metadata to describe the attributes of resources, instructions, and relationships between these instructions.
3. The fact that all this metadata is optional.
4. The fact that it does not account for any external aspects (e.g., user preferences).
5. The documentation is extremely technical.

In addition, the content contained in a SCORM module cannot be adapted to the needs of a specific learner.

While the main advantage of using SCORM is the widespread compatibility with many of today's LMSs, partial implementation of the standard is common in both LMS and SCORM content development software. Given the quality and penetration of the considered standards, SCORM was chosen as the content packaging model for the content of the EIF course, together with use of QTI for testing.

SCORM Impact on the Design of the Learning Experience

As noted earlier, the SCORM standard is not one of the more user-friendly content portability standards. Using it to prepare content for a blended-learning format course posed some significant challenges. One issue we encountered early on was related to the limitations imposed by the SCORM standard to access the internal components of the SCO. That is, instructor feedback for learners' answers to open-ended questions could not be implemented, as we could not find a way to return the instructor's feedback to the SCO. While it is possible to use programming techniques to include predefined feedback, our objective for ease of updates prohibited us to do so. For this reason, the review scenario is implemented using the QTI standard, which allows the instructor to assess learners' answers and provide feedback.

Another significant issue with SCORM is related to how the content is produced. While a uniform implementation of the SCORM player (the software component which displays the content to the learners) is expected, considering possible differences between the various computing platforms where this player will be run, we limited our content development to those programming elements that we knew would work on all platforms. This decision limited the types of content that we could produce. Here again, programming techniques might have helped assuage this issue, but our ability to use extensive programming was limited by our objective of making the content easy to update.

Technology

Content Authoring Tools

Question	Which of the available open-source content development and packaging software tools would fit our needs?
Objectives	Ease of use Maintained, with a clear development path Appropriate for use by non-technical personnel Low or no cost
Decision	Decision deferred; will be made in concurrence with learning management system selection
Tradeoffs	Delayed start of online content creation, which could produce delays in final product delivery Possible dependence on an Internet connection while developing the content in case an online-based tool was chosen
Tradeoffs (cont.)	Possible roadblocks in providing content creation and editing access to multiple users in case an online-based tool was chosen Unknown learning curve for the product that would ultimately be selected

As SCORM only standardizes the way the content is packaged and how it interacts with the host learning management system, the content itself can be created using almost any computer-based tool available. The content can then be packaged into a SCORM module as long as it meets the requirements. Since SCORM was the primary target, we looked for tools that would allow us to create the content and have the ability to package it according to the specifications of this standard.

Our research revealed that there are two categories of computer-based tools able to produce SCORM packages. One category is composed of applications that only package the content, leaving content production to other applications (such as HTML editors, Adobe Flash, etc.). The second category covers the applications that serve a dual purpose, providing both means to create the content (e.g., editors) and the ability to package and export it to a SCO.

Two objectives were considered when searching for available content authoring tools. First, we needed a content authoring tool that would help us bring the existing content online, allow us to create new content as we developed the scenarios, and help us collaborate among the design and development team members. Second, considering that updates could be needed as the requirements, legislation, standards, and audiences change, we were looking for a content authoring tool that would allow us to easily change content, with the potential for future changes to be made by subject matter experts with limited computer knowledge. Given this second objective, our hope was to find an integrated content authoring tool that would provide both content creation/editing capabilities and the ability to export this content to the appropriate standard.

Based on possible deployment options, there are two categories of content authoring tools to consider: desktop applications and web-based tools. With the majority of the web-based content authoring tools still in infancy, the open-source desktop applications we looked more closely at included:

CourseLab—http://www.courselab.com/
eLAIX—http://elaix.org/
eXe—http://exelearning.org/wiki
RELOAD—http://www.reload.ac.uk/
Xerte—http://www.nottingham.ac.uk/xerte/

RELOAD was recommended by ADL, the maintainers and developers of the SCORM content portability standard. Table 1 presents an overview of our findings.

As it turned out, no individual application we looked at met the criteria we required. Since we were also looking at implementing the course using a learning management system, we turned our attention to researching the available open-source learning management system applications, which could provide us with the appropriate content creation and packaging tools.

APPLICATION	PROS	CONS	CONCLUSION
CourseLab	Accepts a wide range of content format; rich media support; familiar PowerPoint-like authoring environment; programmable content interaction; hot spots; built-in test creation.	PowerPoint-line interface limits the content space to a predefined size; difficult to create complex modules.	The limited space available for the content was the turn-off feature as the length of our content varies significantly, making it difficult for learners to access it.
eLAIX	Familiar word processor interface and integration (OpenOffice); support for most of ILIAS[4] functionality; ability to reimport exported modules as well as modules generated by ILIAS; reasonably easy to learn.	Does not support SCORM modules directly; there is a need to install OpenOffice (or one of its clones); limited to be used only with the ILIAS learning management system.	Limitations in export format and ties with the ILIAS learning management system.
eXe	Based on Mozilla Firefox code; supports the development of interactive web content; supports both SCORM and ISM CC; flexible interface; templates; easy to install; easy to learn.	Supports only SCORM 1.2; slow when editing longer content; not actively developed anymore.	Development status and inability to export to SCORM 2004 specifications limit its usability.
RELOAD	Recommended by ADL; flexibility of export formats; platform independent (written in Java).	Provides only content packaging and does not support content creation; some difficulties installing; need for in-depth knowledge of the SCORM standard; fairly technical and difficult to learn.	RELOAD only has the ability to package content created with other applications into a portable package format and requires in-depth knowledge of the packaging standards to be used. It also has a steep learning curve.
Xerte	Rich media support; extended support for programming interactions; interface design capabilities.	Need to learn Adobe Flash ActiveScript scripting language to use interactions; steep learning curve; limited content space.	The limited content space, the need to learn a scripting language as well as the steep learning curve makes Xerte difficult to use.

TABLE 1. Open-source SCORM content development and packaging applications.

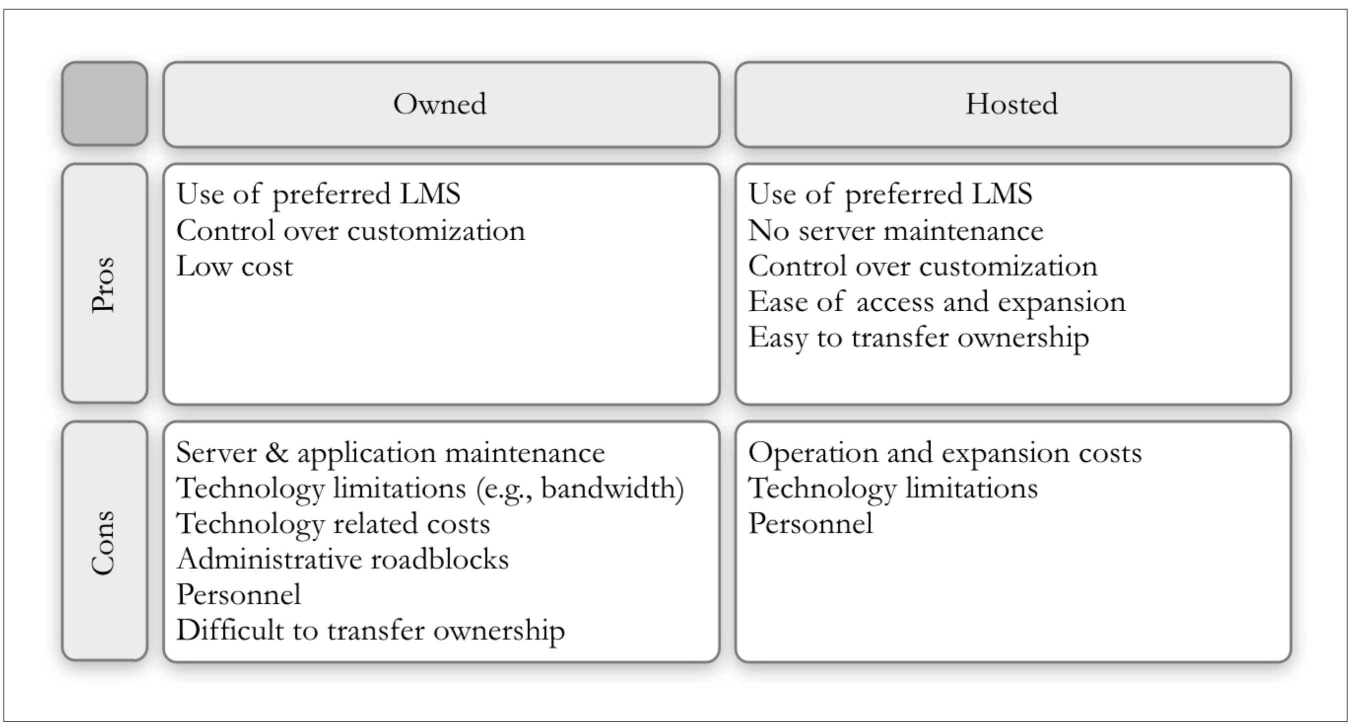

FIGURE 6. Pros and cons analysis of LMS deployment options.

The Learning Management System

Question	Which of the existing open-source learning management systems would fit our needs?
Objectives	Compatibility with the SCORM and QTI learning content portability standards Ease of deployment and maintenance Ease of ownership transfer Support for multiple organizations and groups Serve as example and template for other deployments Serve as repository for the course's SCORM objects
Decision	Department of Energy (DOE) learning management system, based on ILIAS
Tradeoffs	The DOE learning management system was under development, with frequent updates anticipated Limited administrative access Limited availability of social presence tools on the DOE servers Involvement of a third party in the course implementation and delivery
Tradeoffs (cont.)	Accept the limitations of the learning management system content development tools Knowledge of HTML, CSS, and possibly JavaScript needed to develop and maintain more complex content

Our need for a learning management system is two-fold. On one side, the learning management system would host the course and would allow instructors that do not have the appropriate means to offer this course using the framework we provide. On the other side, our implementation would provide us the ability to gain insights into how the structure and delivery of this course works. It would also serve as an example and template for content organization and delivery when ported to other platforms.

Two distinct decisions had to be made: (1) choose a deployment model, and (2) choose the learning management system application. The deployment model had to be decided upon first, as it would limit the range of learning management system applications we would consider later.

For the deployment/hosting solution, we considered three choices:

1. Host using the university learning management system deployment
2. Owned—host it on our own servers
3. Hosted—host it with a third party

Option (1) would not work because we would be using university resources to support courses delivered to third party entities without monetary compensation. A brief pros and cons analysis of the remaining two options is shown in Figure 6.

We considered option (2), hosting the course on our own servers, next. Cost considerations quickly ruled out proprietary learning management system applications. Of the many open-source learning management systems available:

ATutor—http://atutor.ca/
Claroline—http://www.claroline.net/
Docebo—http://www.docebo.com/
Dokeos—http://www.dokeos.com/
ILIAS E-Learning—http://www.ilias.de/
Moodle—http://moodle.org/
Sakai—http://sakaiproject.org/

considering our team's strength in developing and maintaining LAMP (Linux, Apache, MySQL, and Perl/PHP/Python[5]) web applications, we limited our search to the learning management system applications developed using PHP and MySQL (e.g. ILIAS E-Learning). The following elements were considered:

1. Technology—easy to install and maintain with little or no software requirements on the server side
2. Compliance with existing learning standards
3. Active, clear future development roadmap
4. Ability to accommodate multiple institutions and groups of learners
5. Import/export capabilities
6. Testing
7. Grading and reporting
8. Communication and social presence
9. Collaboration tools
10. Interface and usability
11. Content development tools

In evaluating option (2), we also had to consider that our efforts were supported by grant funding, and as such, hosting and updating content in the future were uncertain. Therefore, we had to consider another key element if we hosted the course: transfer of ownership. In our case, transfer of ownership had two key dimensions: transfer of content and transfer of the administration of the learning management system. The most significant problem with content transfer is ease of update. The transfer of the learning management system administration is more complicated, as it requires providing a way to either move the entire learning management system to a different platform (server, organization, etc.) or giving administrative access to the server where the application is installed. The first option poses significant technical difficulties, while the second option might face significant administrative barriers.

While gathering data on the various open-source learning management system applications that met our criteria and considering the ownership transfer issues explained above, our CEWD collaborators learned that the U.S. Department of Energy (DOE) was in the process of developing its own educational portal. The DOE effort is called the National Training & Education Resource (NTER) and includes a learning management system application, as well as a variety of other resources. DOE offered us the option to host our course on their servers and invited us to review their learning management system, a customized solution based on an existing open-source learning management system, ILIAS (http://www.ilias.de/), one of the choices we were considering.

Upon further review, we decided to work with the U.S. Department of Energy to develop our course. The decision we made was based on the following elements. First, ILIAS is a stable LMS with a clear development path that meets most of our criteria. Second, because the LMS is open-source and developed using technologies our team is proficient in, if needed, we would be able to install the LMS on our servers and move the content without difficulty. Third, DOE would manage the servers, courses, and users, which would allow us to easily transfer ownership. Fourth, the LMS provides an extensive content development tool, which would allow us to create and edit the content in situ, making it easy to update the content in the future. Fifth, the DOE LMS implementation separates content development from content delivery. Sixth, each ILIAS (the LMS on which DOE's NTER is based) deployment becomes part of a network of similar instances (installed software), which allows users to find

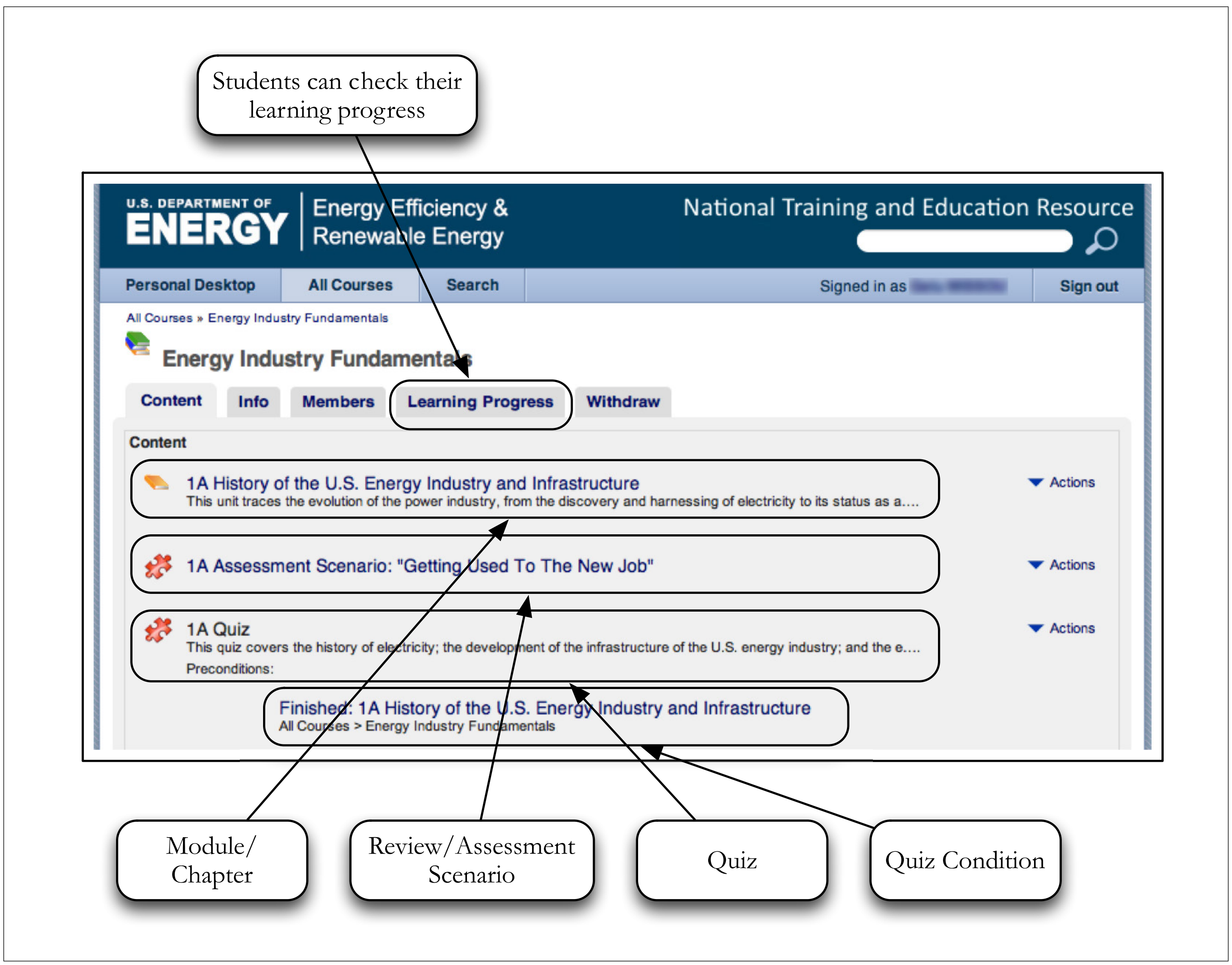

FIGURE 7. Course main page.

and use resources that are not locally available. Finally, the DOE LMS can export the content in a multitude of formats, including SCORM and QTI, depending on content.

The DOE LMS' content authoring tool limitations significantly impacts how the content is designed and delivered. While the editor itself provides extensive functionality to help create and format web content and includes a wide variety of multimedia, its capabilities to design interactive content are limited. Although the content itself does not require interactivity, the delivery of the learning scenarios would benefit from interactivity in the delivery of appropriate feedback to learners' answers. This was especially an issue given that the SCORM standard does not allow the learning management system to access the internals of a SCO, thus prohibiting direct instructor feedback. Also, to personalize the course and content to a desired look and feel as well as to develop and maintain more complex content, some knowledge of markup languages (HTML & CSS) is still needed.

THE FINAL PRODUCT

Currently, the course has been completed and pilot testing is under way. Because the course set up is too complex to be presented in the space available, we include only a couple of the more significant features. Figure 7 shows the main course page displaying the major course components, while Figure 8 shows the SCORM player, which allows the learner to access the theoretical content and the learning scenarios.

The main page of the course, shown in Figure 7, lists the learning modules in the recommended sequence. Each learning module is followed by the associated review scenario and quiz. The quiz can only be accessed if the student has read the content (accessed all content pages) and performed all required tasks (answered all learning scenario questions) in the associated module. This page also allows learners to view their learning progress for each component of the course (learning module, review scenario, and quiz). It also provides access to a variety of other functions. For example, the "Info" tab allows learners to access information about the course (e.g., disclaimers, contact, etc.).

Figure 8 shows the SCORM player. In DOE/ILIAS learning management system, the SCORM player opens in a new browser window. The player window is divided in three major sections: the navigation menu (left), the content area, and the toolbar (top). The navigation menu allows learners to navigate the content freely. The content area can display text, images, formulae, audio-visual components, and questions. At the top of the page, the toolbar allows access to other functionality of the SCORM player.

The learning management system also provides the usual functionality of a learning management system, including user management, test tracking, and manual grading. A variety of reports and statistics are available to the instructor.

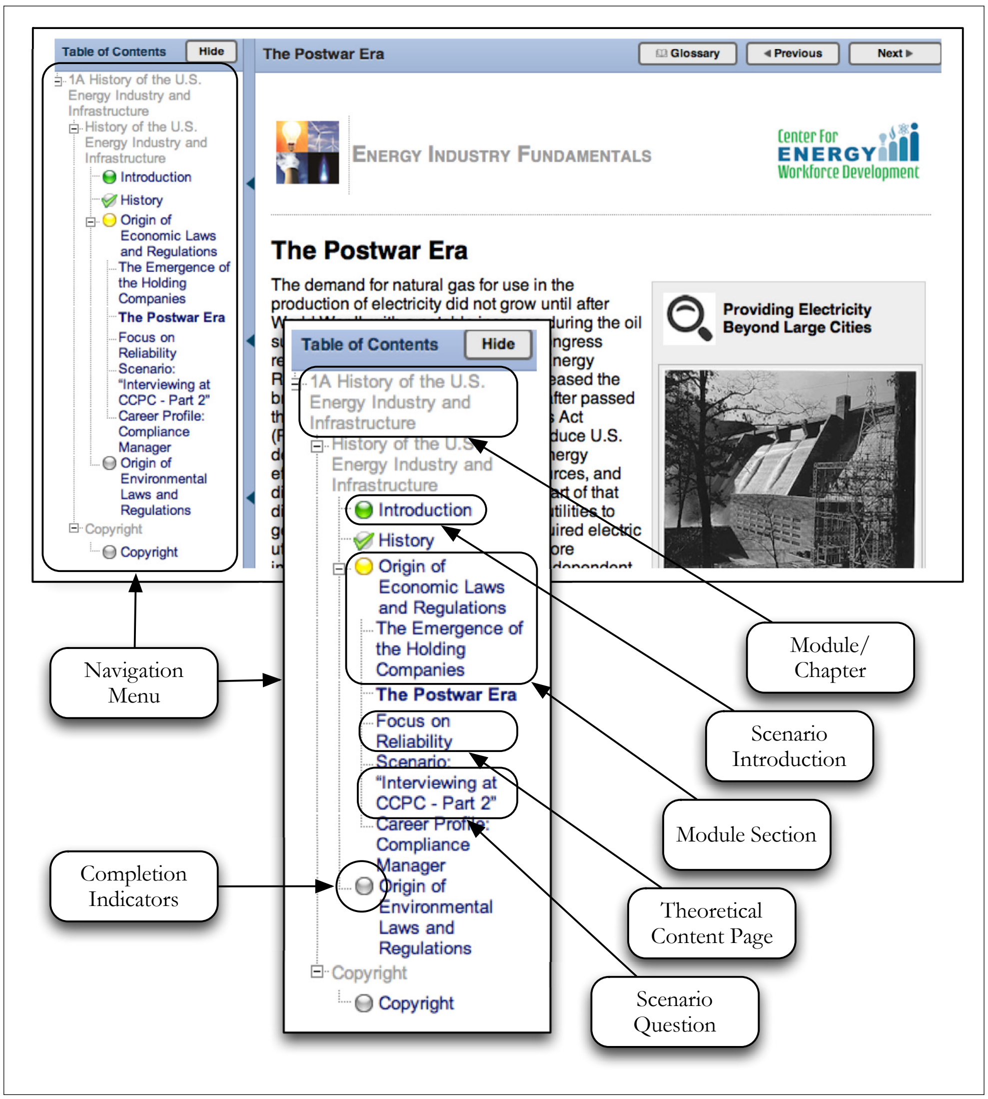

FIGURE 8. The SCORM player window.

DISCUSSION

The SCORM standard is not particularly suitable for deploying a course in an instructor-led blended-learning format; however, the state of learning content portability standards, as well as their widespread implementation in existing proprietary and open-source LMSs, led to its use for this course. To make this work, deviations from the tenets of the SCORM learning content portability standard were necessary.

Implementation of reusability is one of the main SCORM objectives—the ability to recombine the content in different ways—and was only partially achieved in the design and delivery of this course. This happened for two reasons. The first is related to the implementation of the learning scenarios, which were designed to become an integral part the module content. To work through the learning scenario, the learners need to access the theoretical content. When opened, each learning module will run inside a player, which opens outside the LMS main workspace (per SCORM specifications), making navigation to and from other content difficult. To access other course content learners would need to open/close or hide/show the player. Additionally, the learning scenario is designed to cover an entire module, with questions distributed throughout its content, requiring the content to be kept together in the same module.

The second reason is related to the blended format of the course, which required consistency between the printed format and the online format. Therefore, each module in the printed materials was converted into an online learning module, containing multiple SCOs. As a result of this requirement, meaningful content runs across multiple learning objects, and creating relationships with content outside each SCO was not possible.

Due to the limitations of the SCORM standard and of the LMS itself, testing functionality and some of the content had to be implemented using a different standard. SCORM offers little capability for tracking learners' progress. The options available are tracking content navigation, as well as answers to questions. Therefore, the limitations of the SCORM standard to allow the LMS to access its internal components required the tests, quizzes, and review scenarios to be implemented using the QTI standard. The QTI standard provides a wider array of options for feedback and assessment that were critical to incorporating these features.

One might expect that today's technology would have sufficiently evolved to provide the tools for developing SCORM content, but our search proved less than successful. We found very limited options for a content development tool that would be relatively easy to learn and use, with a low or no price tag. Despite the fact that the SCORM standard does not enforce how the content is produced and presented to the learners (as long as it meets the criteria for portability), the tools available today seem to be directed toward developing self-paced modules with little or no instructor intervention. The open-source tools we found that do not limit our options provided only content packaging capabilities. This required knowledge of other software packages and eventually programming and markup languages for content development. In addition, the very technical nature of the SCORM standard specifications makes these software packages difficult to use. At this juncture, if ease of update by non-technical personnel is desired, our experience suggests that no open-source tool we tested would fit this requirement.

From the content delivery point of view, the wide range of similarly featured learning management systems available increases the difficulties in choosing the one that is more appropriate for more complex delivery models. The solution we chose (use of the US Department of Energy NTER learning management system environment) alleviated many issues related to administrating a learning management system and provided a web-based content development tool. This choice did pose challenges to scenario design and implementation. Of these challenges, the most important was to design the learning scenarios considering the need to limit the feedback the learners receive on their answers to the

	Positive/Favorable	Negative/Unfavorable
External Factors	Solid theoretical and instructional design knowledge Instructional design experience Knowledge and experience in developing and using information technology for learning	Limited funding Limited number of SMEs Availability of long-term support
Internal Factors	LMS capabilities Integration in network of similar LMSs Course/user management by third party Stable and tested LMS platform Clear LMS development path Ease of ownership transfer	SCORM standard limitations No control over theoretical content No direct control over LMS settings No control over the course format Limited availability of content development tools LMS under development

FIGURE 9. Project SWOT analysis.

open-ended questions, thus accepting diminished returns for this type of intervention.

While the EIF course is designed to be instructor-led, requiring face-to-face student-instructor interaction, it is likely possible to deliver the course with a strong online component. That is, it is conceivable that potential future delivery might limit the face-to-face interaction to only those activities that require physical presence (e.g., demonstrations, laboratory work, etc.). The knowledge content and tests could then be delivered in an online-only format. In this case, social interaction between learners will be limited and online options for this interaction to continue (e.g., discussion boards, chat, etc.) would be necessary. Unfortunately, neither SCORM nor QTI offer such options. Therefore, each separate course implementation would have to provide its own means for social interaction. Fortunately, all LMS applications have social interaction tools available for use. The remaining issue is to provide instructors with clear instructions for implementing this interaction so that the designed learning experience is maintained.

SUMMARY AND CONCLUSIONS

Given our objectives of outreach, access, portability of content, and ease of future updates, a complete solution could not be reached for this course. This forced us to accept a number of tradeoffs. Currently, portability standards and content development tools are not yet ready for the development of a portable, instructor-led course delivered in a blended-learning format that would be flexible and easy to maintain. This fact, along with our experiences, shows that bringing courses online in blended-learning formats can be a difficult process with many obstacles to overcome.

Our experience shows that the development of such course requires the designers and developers to accept a number of tradeoffs (e.g., deviations from the tenets of the SCORM standard), and these affect both the maintenance and management of the course as well as the learning experience. Figure 9 briefly presents in context a SWOT (Strengths, Weaknesses, Opportunities, and Threats) analysis of our efforts to design, develop, and ultimately deploy the online component of an instructor-led energy industry course delivered in a blended-learning format using open-source software.

While we are considering the possibility of converting this course from a blended format to a self-paced online format, our experience using the existing technology and following portability standards tells us that significant work would be needed. Such efforts would not only include how the learning experience is designed but also rewriting and reorganizing the content.

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ENDNOTES

1. Both the paper-based version and the online version of the EIF course have received accreditation from the American National Standards Institute, which leads to a Certification for the students who pass a final examination based on the course content.

2. In its most general accepted definition, metadata is "data about data". That is, metadata describes the various characteristics of other data. The SCORM standard uses metadata as a way to catalogue the information contained in the Sharable Content Object (SCO). Metadata allows content to be found when stored within a content package or a repository, such as a learning management system.

3. Per SCORM specifications, a Sharable Content Object (SCO) has to be designed to function independently from the environment where it is hosted (i.e., it should be able to run both in both online and offline environments). The only requirement for accessing the content is the availability of a "player" able to display the content in a structured format. For this reason, the internal components of the SCO are invisible to the host learning management system and the communication between the SCO and the host environment takes place in one direction only, from the SCO to the environment. That is, the SCO makes available data related to, for example, the completion status of each of the SCO's components or the results of quizzes or tests. The host environment cannot communicate data back to the SCO and cannot change the content. This restriction prohibits many features, including the instructor's ability to provide feedback to learners' answers. Feedback is only available if it was included in the SCO from the beginning.

4. ILIAS - *Integriertes Lern-, Informations- und Arbeitskooperations System* (German)

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