Teaching and Learning Differently: Personalized E-Books for Learning (PEBL)

Elliot Robson, Peter Berking
Eduworks Corporation
Corvallis, Oregon
elliot.robson@eduworks.com, peter.berking@eduworks.com

ABSTRACT

Although current eBooks are little more than print shown in an e-reader, as a mobile, connected platform, eBooks have the unrealized potential to support more pedagogical approaches than traditional books, including experiential, problem-based, dynamic, and social learning. To realize this potential, the Personalized eBooks for Learning (PEBL) project has developed a specification that enables new capabilities in eBooks while maintaining the advantages of the "book" format. The PEBL project, funded by the US Advanced Distributed Learning (ADL) Initiative, has extended the standard EPUB3 format to enable eBooks to communicate with other systems in live, virtual, simulated, and constructive environments; to embed and exchange data with simulations, games, and intelligent tutoring systems; and to serve as competency-based training environments.

This paper describes new pedagogical approaches that are enabled by PEBL that go beyond the affordances of current eBooks, and outlines the modular and expandable structure of the PEBL specification. New capabilities include: book content triggered by the learner skills and competency levels; instructor-driven content brokering; dynamic individual and team progress dashboards and native analytics; and exercises in which learners communicate and collaborate with each other. These can each be separately provided by different learning technologies, but not all together in the convenient, media-rich, portable eBooks.

To demonstrate these capabilities, this paper reports on a next-generation cyber security eBook that contains examples of many of the new features and functionality available through PEBL-compliant eBooks and eReaders. We discuss both the pedagogic approaches and technical implementations used in the Cybersecurity demonstration PEBL eBook, and how this eBook has integrated with other technologies using the ADL's Total Learning Architecture (TLA). Finally, this paper outlines the possibilities for using PEBL-enabled eBooks in conjunction with virtual and mixed reality training, and we outline other implementations and specifications related to PEBL that have resulted from the Institute of Electrical and Electronics Engineers (IEEE) Actionable Data Book Industry Connections activity.

ABOUT THE AUTHORS

Elliot Robson is VP for Research at Eduworks Corporation and Principal Investigator (PI) on the PEBL project. Elliot designed numerous adaptive tablet-based learning materials and educational games while at Amplify learning, a leading US educational technology provider, and has served as PI or Co-PI on related projects funded by the US ADL Initiative and the US Army Research Laboratory (ARL). He has been an author or co-author on previous I/ITSEC papers and tutorials and has helped develop competency-based tools and curricula for professional development and other training/education organizations. Mr. Robson has a Masters of Public Policy from the University of Michigan and has worked for the United Nations as an education system analyst.

Peter Berking is a Senior Learning Technologist at Eduworks Corporation and Lead Instructional Designer on the PEBL project. He has more than 22 years of experience in a broad base of instructional design and development activities, for products ranging from technology-driven e-learning products and performance support systems to instructor-led courses. He is a subject matter expert in instructional design and advanced learning technologies, publishing articles for industry publications and presenting at conferences. Mr. Berking was embedded on staff as the Senior Instructional Designer at the US ADL Initiative in Alexandria, VA from 2008 - 2016. He has a Masters in Education from University of California Berkeley.

Teaching and Learning Differently: Personalized E-Books for Learning (PEBL)

Elliot Robson, Peter Berking
Eduworks Corporation
Corvallis, Oregon
elliot.robson@eduworks.com, peter.berking@eduworks.com

HARNESSING THE POWER OF MODERN LEARNING TECHNOLOGY IN EBOOKS

Functionally, current eBooks are print books converted for display in an eReader. While the Web, desktop software, and mobile app producers add more and more interactivity, media, and communications capabilities to their products, eBook publishers are holding back, possibly out of fear of losing sales due to disrupting one of the most established and familiar product designs in human history: the book. This trend forces educators to choose between textbooks (and eTextbooks) with validated and effective content, and new pedagogy available through electronic, simulated, and mixed reality training. Millions of eBooks are sold every year based on the basic conveniences of the book format:

- Portability
- Structure (i.e., usually a table of contents, with headings for topically organized content)
- The ability to consume content in either linear or non-linear fashion (i.e., browse and skip sections by flipping pages)

Add to these the advantages of current eBooks:

- Dynamic media objects
- Search function
- Ability to highlight and annotate without damaging the resell-worthiness of the book
- Links to external content objects
- Massive portability (i.e., whole libraries of books in a small form factor)
- Cost effectiveness to distribute and update

However, sales of eBooks have started to fall off. Sales for trade publishers fell 14% in 2015 compared to 2014, and eBook units purchased as a share of total books purchased fell from 35.9% in April 2015 to 32.4% in April 2016. This is blamed in part on the limitations of eReaders (Milliot, 2017). To address the weaknesses of eBooks, the eBook publishing industry recently reached a major milestone: on 1 Feb of 2017, the International Digital Publishing Forum (IDPF) and World Wide Web Consortium (W3C) officially merged (W3C, 2017). This reflects an acknowledgment by the IDPF that it is now time to align eBook technologies with modern interactive Web technologies.

Nowhere is this alignment more important and potentially transformative than in the field of learning, education, and training (LET). As a mobile, connected platform leveraging the power of tablet hardware, eBooks have the unrealized potential to support many new learning technologies and their underlying pedagogical approaches, including, for example, virtual immersive environments (VIEs) that enable experiential learning. To realize this potential, the Personalized eBooks for Learning (PEBL) project funded by the US Advanced Distributed Learning (ADL) Initiative is developing an open specification that enables many capabilities currently found in advanced learning technologies to be part of eBooks. The PEBL project has extended the standard EPUB3 format to enable eBooks to communicate with other learners, eBooks, learning systems, and VIEs; to embed and exchange data with other systems in a learning environment; to serve as competency-based training environments; and to adapt and broker content to user performance within and outside of the eBook.

A good place to start in improving learning through eBooks is with the eTextbook, since textbooks are arguably the most fundamental, universal tool for learning. The natural primacy and familiarity of the textbook as the trusted source of authoritative learning content and reference information is a convenient and powerful leverage point for instigating change. PEBL anticipates that its initial implementation use cases will focus on eTextbooks, although improvements to eBooks for learning through PEBL will be usable for the entire universe of use cases for eBooks,

learning or non-learning related, since they appeal to such commonly experienced user requirements as connected use and interactive engagement.

THE PEBL PROJECT

The PEBL project has its roots in an IEEE Industry Connections Actionable Data Book (ADB) project (https://ieee-sa.imeetcentral.com/adb/). ADL and Eduworks personnel have participated in the Institute of Electrical and Electronics Engineers (IEEE) ADB working group, and the Chair of the project is on the PEBL team. PEBL is collaborating with the IEEE ADB effort throughout the project. In this regard, PEBL will serve as a testbed for proposed standardizations, and the specifications and methods developed by PEBL are informing the IEEE work.

The PEBL project is a three-year project with a base year and two option years. At the time of this writing it is approaching the end (1 July 2017) of its first year; many of the features mentioned in this paper are not implemented yet in a prototype, though they will be part of the specification and may be demonstrated in an option year version of the prototype. The three-year PEBL project structure corresponds to the progression through Technology Readiness Levels 4-6 (TRLs) (Wikipedia, 2017) and levels of evaluation (Kirkpatrick levels 2-4 – Kirkpatrick, 1991). A PEBL-compliant eBook called *Phishing: A Method of Social Engineering in Cybersecurity* has been produced as prototype that demonstrates many of the features enabled by PEBL-compliant eBooks. Evaluations of the year 1 prototype has been conducted as part of the ADL Total Learning Architecture (TLA) evaluations April 17-21 2017 at the U.S. Army John F. Kennedy Special Warfare Center and School (SWCS) at Fort Bragg, N.C.. At the time of this writing, evaluation data has not been processed and compiled, but the PEBL prototype eBook demonstrated the power of an integrated eBook by providing over 8,000 xAPI statements out of a total 19,000 reported through the TLA. The PEBL project will eventually make use of the ADL report on this data in determining revisions to the prototype and functional direction for the specification for year 2 and 3 of the project.

Currently ADL and Eduworks staff are working with several DoD and commercial entities who have shown interest in adopting PEBL for particular eBook use cases ranging from training to interactive reference materials.

The goal of the PEBL project is to create an open specification (and ultimately an open standard) for a new eBook platform that addresses the opportunity to improve learning described in the previous section. The specification is a reference model that combines existing standards, including:

- HTML 5
- Experience API (xAPI)
- EPUB 3
- W3C Widgets
- Representational state transfer (REST)

The platform consists of the following major components:

- eReader
- eBook
- Services architecture

The project has demonstrated a simple implementation of the specification in a prototype (as described above), and will be supporting ADL in transitioning the specification to government and commercial implementers. The platform builds on and greatly extends the EPUB 3 format, and the eReader software is based on the open source Readium platform. The objectives for the project are to:

- Create a new cross-platform open learning specification that is more effective than traditional eBooks for learning.
- Integrate with the ADL TLA as an activity provider and control point for learning experiences within this environment model.
- Create a plug-and-play architecture that allows creative assembly of products into a myriad of solutions while avoiding vendor lock-in.
- Inspire and enable new learning designs and learning science-based approaches through greatly expanding the technology affordances of eBooks.

- Enable product improvement cycles, progressive adaptation of content to learners, and advanced assessment based on improved behavior tracking.
- Position learning to be ready to take advantage of the emerging 5G mobile network standard which will greatly enhance communication with tablet devices.
- Stimulate the educational publishing industry to think differently about the untapped potential of eBooks for learning.

A fundamental guiding principle for the PEBL platform is to make learning technology enhancements to eBooks invisible. In other words, PEBL books should retain the look and feel of eBooks; they should not appear as a completely different and new platform to the user, with new interfaces, new consumption paradigms, etc. Content adaptation and tracking happen behind the scenes in a way that should not be disruptive to the familiar experience of reading an eBook. This will make a big difference in the acceptance of the platform to learning audiences.

The Importance of the Emerging 5G Standard

A major project goal is to be ready to take advantage of the emerging 5G mobile networking standard. Technology-enabled learning today relies more and more on low latency, high bandwidth connectivity. Learning environments deliver and manage learning experiences from cloud servers; end-user applications must make frequent reads and writes to learner profiles and competencies stored in the cloud; learner micro performance tracking (i.e., using xAPI) sends copious data to learning record stores and tracking databases; and huge VIE files are either downloaded or streamed from cloud servers.

As the trend towards using tablets for education and training continues, there is a pressing need for wireless connectivity that does not rely on being limited to wireless networks, but uses mobile telecommunications connections. As the IEEE 5G Initiative Standards Working Group (2017) states,

> "…faster and more effective learning modalities are needed to meet the demand for rapid continual learning and requalification, especially in STEM [science, technology, engineering, and math] fields…These are being developed and deployed in limited quantities today, and 5G has the potential to bring these into the mainstream by providing the required low latency, high bandwidth connectivity on untethered devices. … 5G has the potential to be the tipping point that moves online education and training from its current state of replicating traditional methods to a future state of active, compelling, adaptive, networked learning applications and, as such, to profoundly change the way we teach and learn." (p.1, "Sponsor: Computer Society Learning Technology Standards Committee (LTSC)" popdown panel)

PEBL takes advantage of 5G in significant ways, as described later in the "Need for eBooks to Operate with Environments" section.

LIMITATIONS OF CURRENT ELEARNING PLATFORMS

Web-based ELearning

Web content designed for learning (under the universally accepted label of "eLearning") has proven to be effective for learning (Fletcher, 2010). It has been an industry standard since the late 1990's. However, compared to eBooks for learning (especially eTextbooks), Web-based eLearning has some limitations:

- It is not designed for large quantities of text and periods of intensive, sustained consumption of text-based content (such as required for textbooks). Part of the reason for this is that text readability enhancements (such as those found on the Kindle platform) are generally not included in browsers or desktop computer displays.
- It is not easy to retain the flavor of familiar legacy printed books (such as textbooks) when converted to web pages.
- It is searchable but cannot be easily browsed like a book.
- It is not generally designed for dynamic, real-time content brokering
- It is not usually optimized for tablet device delivery, though this is changing, since tablets are becoming more common as learning delivery devices (Cavanagh, 2015).

- It is not self-contained like an eBook. Web-based eLearning relies on Internet client-server architecture, thus requiring constant connectivity.

Current EBooks for Learning

EBooks for learning, though common in K-20 education, are not in widespread use in corporate training. Part of this is simply due to the cost of tablets. Desktop computers are seen as a necessity, but tablets are not, and "bring your own device" (BYOD) is not a reliable strategy since they are not universally owned like smartphones. But there are other factors. Current eBook platforms have the following limitations:

- Proprietary formats inhibit creative implementations and require pay-to-play.
- Adaptivity, content brokering, and personalization opportunities are limited.
- Ebook text is static—it does not dynamically adapt to internally or externally stored learner competencies, metrics, profiles, etc..
- EBook platforms do not make use of the hardware capabilities of tablets, such as GPS and radios.
- Formats do not support new and more effective pedagogies derived from learning science such as:
    - Constructivist learning
    - Social learning
    - Spaced learning
- There is limited tracking of learner behavior.
- EReader designs relegate them to only a 'content player' role within a learning experience.
- They lack ability to interwork with or control other components of the larger learning environment or learning experience, especially:
    - LVC simulations
    - Mixed reality applications
    - Intelligent tutoring systems

THE NEED FOR A STANDARDS-BASED, FEATURE-RICH EBOOK PLATFORM FOR LEARNING

Proprietary software can turn tablets into powerful learning environments. However, there is no interoperable **open standards-based** approach that supports the same capabilities in a format that is easily developed, published, and used. Formulating this standards-based approach is the goal of the PEBL project, in collaboration with IEEE, a standards development organization (SDO), in the form of the IEEE ADB project.

Some EPUB3-based learning publishers are enhancing their publications with advanced features such as embedded dynamic media, interactive widgets, and communicative learning management functionality. These are not usually difficult to do in an eBook and do not violate the EPUB 3 standard. However, the means for incorporating them is not defined in any specification or standard, EPUB 3 or otherwise. Thus, these publishers are hesitant to heavily invest in software engineers and data scientists to create these kinds of enhanced eBooks, since their proprietary custom code could quickly become a "loser" in the race towards widely adopted eBook formats and universal compatibility with other popular learning software (including eventually internet of things (IoT) devices).

Mobile learning apps (i.e., with reader functionality built in) run natively and thus faster on tablet hardware and have access to the full functionality of the device (GPS, camera, motion, mic/speakers, etc.), thus can be much more feature-rich than eBooks, supporting a wide variety of pedagogical approaches, technologies, use cases, content types, etc. They can also be better designed to interact with a publishers' other online learning assets and systems. But these mobile learning apps present even more of an interoperability problem, since they tend to require more complex and different codebases and interfaces and thus are harder to define in a universal way.

PEBL attempts to bring together the best of both of these worlds in a reference model of widely-used standards that interworks with or embeds modern learning technologies, tablet hardware and operating system (OS) affordances, and a robust and flexible communications backbone (xAPI specification). As with any standard or reference model, it needs to carefully strike a balance between specifying details of how a feature must be implemented, thus limiting innovation and creativity, vs staying out of the implementation details arena, all the while providing a stable base for content creators, developers, and authors, ultimately leading to authoring tools that enable quick and easy implementation of well-defined content features. The PEBL project relies on the IEEE ADB working group, a

collection of world-wide stakeholders and experts (including those with experience in standards development) that has been meeting for 2+ years, for defining requirements that strike this balance.

As mentioned before, a key goal of PEBL is to make the learning technology layer as invisible as possible, hiding complexity of implementation and affordances. The reference model will support features such as content adapting to student competencies read in from external systems in a way that does not interfere with the student's experience of the PEBL book as an eBook.

THE NEED FOR EBOOKS TO INTEROPERATE WITH ENVIRONMENTS

As mentioned earlier, communication with other learning technologies in an environment is greatly enabled by emerging 5G mobile network technology. In the context of the ADL's Training and Learning Architecture (TLA) environment, the eBook is a platform that can, with proper enhancements identified by PEBL, take advantage of 5G technology in enabling robust communicative capabilities such as xAPI analytics, competency frameworks, learning object and digital media repositories (including user-generated content repositories), learner profile services, and other affordances to improve training effectiveness. Also, research by Rupley *et al*., 2015 suggests that the ability to thread different forms of web-delivered media into platforms such as eBooks can help struggling readers in STEM areas, and there is strong evidence that the adaptive and interactive pedagogies supported by eBooks operating within a learning environment can have significant positive effects on learning outcomes (VanLehn, 2011; Connolly *et al*., 2012).

As discussed in the PEBL Features Overview section, many important learning enhancements rely on data sent to and from other learning environment components (including other PEBL books). These components, communicating with PEBL, generally support experiential learning. Social networking functions can be leveraged for this type of learning in order to facilitate learners accessing the resources they need to engage in a learning experience. PEBL enables these functions and allows learners to find and pull ad-hoc learning resources as needed. In this way, the PEBL platform becomes the "command and control" center or "learning experience manager" for learning experiences. This also applies to managing virtual labs and practicum experiences of many types.

If advanced technologies such as simulators, IoT virtual lab devices, or mixed reality (MR) systems are part of a learning environment, this "command and control" aspect of PEBL can be used to monitor learning activities and provide feedback but also to send information from learning assessment tracking in the book to the external system, in order to control the pace, topics, and parameters of learning. PEBL can also seamlessly enable trainees to access the operation manuals, checklists, and instructional material they would normally use on a tablet. By using standardized application programming interfaces (APIs), the same PEBL book can be updated independently of a training environment and be used for training on similar equipment, possibly produced by different manufacturers. Finally, even if eBooks are only used to present content and deliver assessments, a connected eBook can enable one instructor or observer to interact with and personalize the learning experiences for multiple learners at the same time.

PEBL PROTOTYPE

As mentioned earlier, the capabilities of PEBL books are being prototyped, demonstrated, and evaluated through a cybersecurity book on social engineering (specifically, phishing). This topic was identified by ADL as helping fill a gap in offensive cybersecurity training identified by the DoD Office of the UnderSecretary of Defense, Force Education and Training, and is ideally suited to take advantage of the pedagogical affordances of PEBL books. Organizations such as the National Initiative for Cybersecurity Education (NICE), the National CyberWatch Center, and the IEEE Cybersecurity Initiatives have created frameworks and curriculum for cybersecurity that have been used by ADL to derive competencies and high quality, vetted content for the book. In addition, many aspects of social engineering lend themselves to hands-on, problem-based, and collaborative learning activities that PEBL books support. Since PEBL books can run code, widgets can be developed that allow students to create and defend phishing attacks. Topics such as pretexting, elicitation, and information gathering can be presented at widely varying depths depending on the technical background of the learner (see *Content adaptation and multi-level content* in the next section), adding significant pedagogical value to the ability of PEBL books to adapt to learner models and of instructors to broker content.

PEBL FEATURES OVERVIEW

Content and Functionality Provisioning

A key PEBL feature is smart provisioning of content and functionality between cloud services, the eReader, and the book, in order to balance between being able to operate in standalone mode (like most current eBooks) and operation requiring connectivity. The criticality of this in the case of PEBL is simply that mobile connectivity, although not a tether like wireless network connectivity, is still a tether. It is important for PEBL books to be self-contained to as high a degree as possible, to account for disconnected use cases (military personnel at a forward operating base or on ships, for instance) that users of books often expect. Furthermore, users do not like to use up their data plan on huge files, especially if it for work, not personal training purposes. Finally, economically disadvantaged users may not have or be able to afford data plans.

PEBL algorithms take into account such information as file sizes, available bandwidth, planned periods of non-connectivity, user preferences, and device capacity for the device to provision items on a book by book basis, once a key action has occurred, such as a book being requested to be launched. Features in a PEBL book that require connectivity are identified to the user so they can plan their learning experience location accordingly. Whereas the user may be able to skip streaming videos that are non-essential content and start consuming the content anyway, they may want to wait until they have uninterrupted connectivity to consume a book that has cloud-delivered widgets with essential content or activities contained in them.

A key support for provisioning is that if the device goes offline, then calls made to external services will attempt to be serviced from device local stores (e.g., caching learning record store (LRS) on the device), and when a connection to the network is reestablished, PEBL will redirect future calls to the appropriate network services and synch data stored locally to the service.

Content Adaptation and Multi-level Content

Smart provisioning of content and functions as described above is an example of a feature that provides convenience for consumers of learning. Content adaptation and multi-level content is an example of a feature that addresses pedagogical effectiveness. Multi-level content is useful in maintaining the user in the zone of proximal development, i.e., the level of difficulty best suited to the individual learner. The feature allows the user to switch between different versions of content on an individual paragraph level, and the default version can be set by external systems, not just by the learner. There are many ways this can be used, such as:

- Multiple complexity levels of content (novice, intermediate, advanced) in the same book
- Multiple reading levels in the same book
- A scenario where the user could switch between input parameters or outcomes.

In the first bullet above, the learner can compare how a novice thinks about a topic vs how an expert does. This can be a very powerful learning aid in and of itself, regardless of the specifics of how the different versions of content are written.

An example of multi-level content switching in the current PEBL cybersecurity prototype book is shown in Figure 1. In this example, there are two versions of the content: “Basic” and “Detailed”. Touching the star-shaped button controls which the user sees.

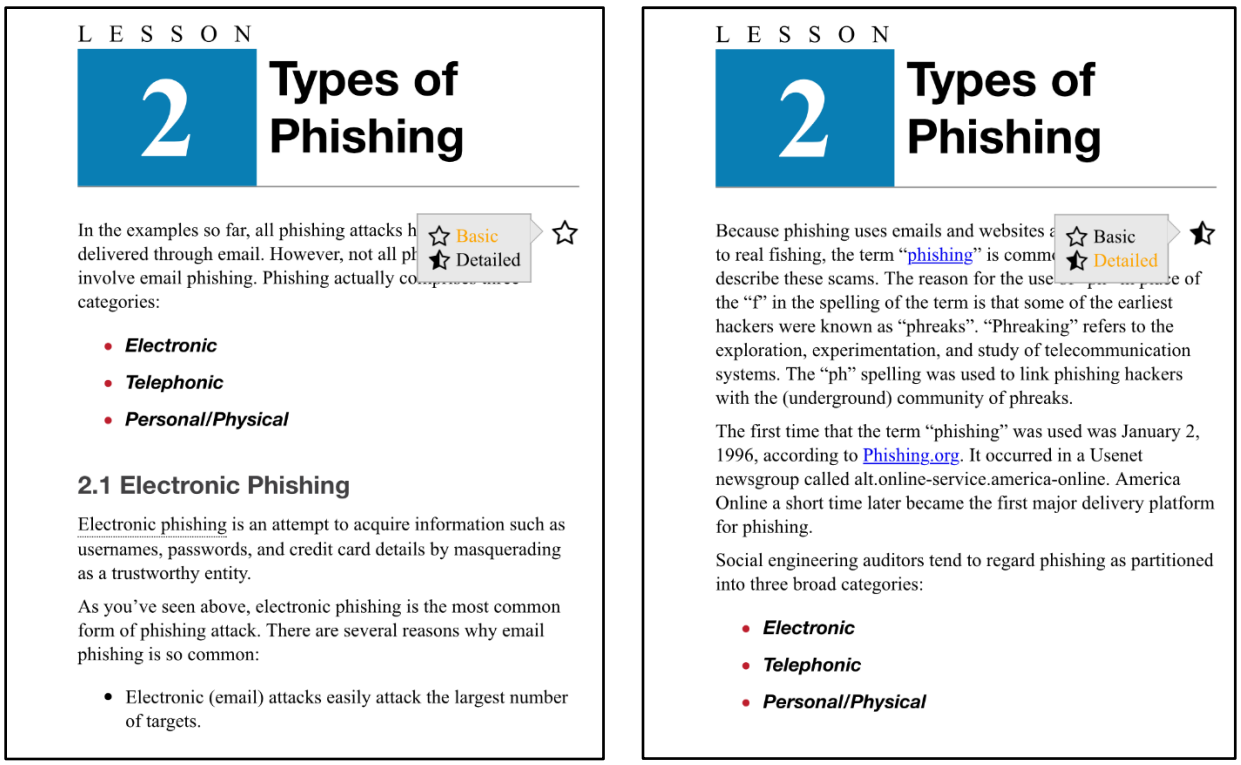

Figure 1. Example of multi-level content switching

Leveraging the ability of content to switch between these levels allows content adaptation, where external systems within the TLA or other environment control content levels, visibility, etc.. This switched content can dynamically adapt to a learner's competencies or profile information, as communicated to the PEBL book by external TLA or other environment components.

Multi-user Interactions

The simplest form of multi-user interactions will be via chat and widgets that display Google docs. These are supported in all PEBL books and allow real time collaboration and group work to be built into exercises. Since widgets can read the activities of other students from a shared LRS (assuming connectivity), it is straightforward to implement widgets that allow multiple actors to move objects on a shared canvas, and even more complex interactions can be enabled by encapsulating applications running on a server (such as a serious multi-player game) in a widget.

Dashboards and Analytics

Analytics are displayed on a dashboard available from within the PEBL book or separately by an instructor or stakeholder. xAPI statements that include multiple attributes and metadata are sent from the book as the user is consuming it. These xAPI statements are then extracted from the LRS and transformed into a format required for the data analytics application. The analytics engine summarizes, correlates, and presents it as visualizations to a web-based reporting dashboard.

Instructor-guided content brokering is supported by the PEBL dashboard. The dashboard is a stand-alone HTML5 application suitable for desktop or tablet use. It reads activities reported from the PEBL books of all students in a class, process these, and display derived descriptive analytics. For example, the dashboard might show where students are in the book, which passages have been frequently highlighted or annotated, how students are faring on assessments, and where students seem to be skimming or getting stuck. The dashboard also retrieves and displays competency profile information from a competency reporting service. Using the dashboard, instructors can drill

down to individual students and recommend resources or actions. Instructor recommendations display via a widget or reader tool.

The following is a sampling of specific items that are tracked in PEBL via xAPI:

- Chapters/lessons/activities completed (because PEBL books are reflowable, not fixed layout, "pages read" makes no sense). Reporting can include re-read frequency and estimates of reading speed, by individual and group aggregate.
- Time Spent
    - Per book
    - Per chapter/lesson
    - Between actions
    - In quiz / per question
- Audio and video usage
- External URL Launches
- Learner performance on assessments and activity nodes

The last item is obviously important for learner performance tracking and training effectiveness evaluation purposes; other items are useful as paradata for producers and stakeholders, to be able to improve their product. Except for the last bullet, these items are not generally tracked in current eBooks or eLearning.

Future versions of PEBL will feature a Query Builder Wizard widget so that the instructor can make ad hoc queries to the LRS to enable special monitoring of individual or group performance and especially for investigation of emergent instructional problems (or exceptionally positive indicators).

PEBL also supplies feedback to the learner through a local dashboard available within the eReader interface. The local dashboard queries the local LRS and presents learning feedback to the user whether offline or online. It is not as powerful as the online analytics dashboard, as all analysis and calculation occurs within the eReader application or the in-book widget. It displays specific analytics to the learner or instructor whether offline or online. Operating offline, aggregate data not generated by the learner is in its state from the prior LRS synchronization. The local LRS updates itself from the remote LRS periodically when the PEBL eReader has an internet connection.

Other Features

Other important PEBL features include the following:

- Non-traditional assessments (through the use of widgets)
- Discussion forums embedded within the book, where learners communicate with each other and with instructors as part of a learning experience. This communication is contextualized to specific locations, questions, and topics within the book. Users can rate comments and explain their ratings.
- Annotations associated with bookmarks and highlighted passages that can be shared with other learners and instructors

These and other innovations will enable widespread implementation of modern pedagogical models such as the following:

- Project-based learning
- Social learning
- Constructivist learning
- Spaced learning
- Flipped classrooms
- Gamification
- Microlearning

In the case of the PEBL Cybersecurity prototype book, project-based learning and social learning are dominant pedagogical approaches. Project-based learning is designed into the book through native widgets that allow learners to create and discuss mock plans for a phishing attack with other readers, as a practical exercise after they have absorbed the supporting information about how such attacks are constructed, and seeing examples. Social learning is

integrated into the book through native widgets that pose questions requiring higher order thinking skills and manipulation of the content to answer, and allow learners to discuss their answers with other readers of the book. Both of these features are embedded within the book's flow of content to allow learners to interact without leaving the context of the book, avoiding forcing learners to switch to a social media tool, for instance.

EXAMPLE PEBL SCENARIO

The following scenario exemplifies the unique and transformative power of PEBL to manage and access learning, authoritative source reference material, and operational tools within a single book, and exemplifies many of the PEBL features described above.

Background: John is an aircraft maintenance mechanic trainee in the U.S. Air Force. He has just embarked on a certification course to change tires on a C-130 aircraft. He has some training and experience in aircraft maintenance, but has never changed tires on any aircraft before.

NOTE: Through the power of emerging 5G mobile networking technology, there is no latency whatsoever throughout this experience. The learning experience is delivered and controlled through his PEBL book running on a tablet mobile device, at any location.

1. John downloads the C-130 Tire Changing Certification PEBL book from his Wing's training book repository.
2. The book presents a short video demonstrating the entire tire changing procedure.
3. The PEBL book knows from John's competency profile that he has never changed tires on any aircraft before. The PEBL book presents a textbook-like introduction explaining generalities of aircraft tire changing. In this introduction, John uses embedded Discussion widgets to discuss topics with his fellow students in the certification program. Some paragraphs in this introduction are available for "content morphing"; he tries out the Intermediate level text on those paragraphs to see if he can handle it. He finds that it is too technically difficult for him, so he switches those paragraphs back to Novice level, but, on the advice of his commander, he sets himself a goal to eventually master not only the Intermediate but the Advanced level content in those paragraphs as well.
4. He interacts with an intelligent tutoring system (ITS)-mediated training module (including closeup videos of details of the procedure and 3D animations) presented within the book. This ITS module assesses his performance throughout an interactive learning experience in "stealth assessment" mode. Data regarding his performance is collected into his student profile using the Experience API (xAPI). The ITS module focuses on outlier conditions, troubleshooting, and TTPs (tactics, techniques, and procedures) at a detailed level.
5. The operational checklists and tech manual for C-130 tire changing are displayed by the ITS through the PEBL book and referred to throughout the session (John can also access them at any time through the PEBL eReader bookshelf). At one point in the ITS-mediated experience, the tech manual is displayed to John with details about a specific technical point. John highlights a passage in the tech manual and indicates through the PEBL interface that he would like help from an instructor to answer questions about this passage. An on-call coach opens a video chat session with him and answers his questions.
6. The PEBL book presents a 3D simulation of the tire changing procedure. The simulator adapts to John's performance in the ITS module, emphasizing certain aspects of the procedure on which he showed weakness as well as the topic he highlighted and talked to an instructor about. The simulation requires more practice on these portions.
7. John does a dry run of changing a tire for the first time on physical practice training equipment, using his operational checklist (in training mode) displayed in the PEBL book. This practice equipment is instrumented with sensors. A remote instructor observes via video feed and sensor input, and rates John's performance using a dashboard displayed in his PEBL Reader.

8. The book presents a dashboard with a summary of performance to John, and generates a list of remedial learning material and activities. The instructor personalizes this list further, and sets a learning path through the book that includes morphing some paragraphs to Intermediate level.

CONCLUSION

In this paper, we have described PEBL, an open source eBook for learning platform currently under development that merges key aspects of eLearning technology, mobile device affordances, and eBook technology. In addition to the synergies derived from the interworking of these three sets of functions, it is expected that the convenience and familiarity of the eBook format for this platform will propel widespread acceptance to such a degree as to support cost-effective development of the next generation of learning applications. This platform is robustly positioned for adoption by publishers and content authors due to the fact that it is a reference model based on established standards and informed by industry requirements collected by an IEEE working group. This platform has the potential to transform learning through fully leveraging 5G technology and achieving compatibility with learning environments like the ADL TLA, ultimately creating an "Internet of Books" for learning.

ACKNOWLEDGEMENTS

We would like to thank Dr. Sae Schatz of ADL for sponsoring the PEBL project, and Dr. Karen Cooper for project oversight as the ADL Technical Point of Contact. We would also like to thank the IEEE Learning Technology Standards Committee Actionable Data Book working group chaired by John Costa for their inspiration and conceptualization of functional requirements and design of PEBL.

REFERENCES

Cavanagh, S. (2015). Tablet, smartphone use in K-12 rises, and learning apps have big presence. *Education Week.* 9/25/2015. Retrieved April 4, 2017 from http://blogs.edweek.org/edweek/DigitalEducation/2015/09/tablet_smartphone_use_in_k-12_.html

Connolly, T. M., Boyle, E. A., MacArthur, E., Hainey, T., & Boyle, J. M. (2012). A systematic literature review of empirical evidence on computer games and serious games. *Computers & Education*, *59*(2), 661-686.

Fletcher, J.D. (2010). Research foundations for the Advanced Distributed Learning Initiative. *Institute for Defense Analysis Document D-4118.* August 2010. Alexandria, VA: Institute for Defense Analyses. Retrieved 8/2/2017 from http://www.dtic.mil/get-tr-doc/pdf?AD=ADA533830

IEEE 5G Initiative Standards Working Group (2017). Standards article. Retrieved March 31, 2017 from http://5g.ieee.org/standards (LTSC section).

Kirkpatrick, D. (1991). *Handbook of Training Evaluation and Measurement Methods.* Houston, TX: Gulf Stream Publishing.

Milliot, J. (2017). As e-book sales decline, digital fatigue grows. *Publishers Weekly*. 6/17/2016. Retrieved March 30, 2017 from http://www.publishersweekly.com/pw/by-topic/digital/retailing/article/70696-as-e-book-sales-decline-digital-fatigue-grows.html

Rupley, W. H., Paige, D. D., Rasinski, T. V., & Slough, S. W. (2015). Multi-touch tablets, e-books, and an emerging multi-coding/multi-sensory theory for reading science e-textbooks: considering the struggling reader. *Journal of Education and Training Studies, 3*(4), 1-8.

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

W3C (2017). *New roadmap for future of publishing is underway as W3C and IDPF officially combine*. Retrieved March 30, 2017 from https://www.w3.org/2017/01/pressrelease-idpf-w3c-combination.html.en

Wikipedia (2017). *Technology readiness levels*. Retrieved April 4, 2017 from https://en.wikipedia.org/wiki/Technology_readiness_level