PeBL: A Next-Generation Mobile Platform for Adaptive Immersive Training

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Abstract: The Advanced Distributed Learning (ADL) Initiative's open source Personalized eBooks for Learning (PeBL) project (www.peblproject.org) has developed a specification based on industry standards that enables eBooks to become versatile mobile training platforms running on standard tablets and eReaders. PeBL eBooks include Experience API (xAPI)-based reporting and data analytics; can adapt and change their content based on user profiles or preferences; can embed or launch interactive elements ranging from assessments to simulations and virtual reality applications; enable learners and instructors to collaborate via discussion forums, voice, and shared annotations; and can make use of mobile device sensors such as a GPS or accelerometer. This paper discusses the PeBL specification, its architecture, and use cases. Use cases discussed include "field notebooks" with embedded resources and built-in connectivity to networks of experts; and cybersecurity training eTextbooks that adapt to learner models shared with games, simulations, and eLearning systems.

1 Introduction

eBooks have high potential as platforms for education and training. They retain the readability, portability, and organizational advantages of print materials while providing the computational, communication, and geolocation capabilities of mobile, connected devices. Those that are created using the EPUB 3 standard also have the potential to offer the full range of interactivity, user interface, and reporting functionality available in HTML5 (the EPUB 3 codebase). This is a powerful combination that could significantly improve traditional training and enable new instructional tools, but this requires multiple components to work in concert, including mobile devices (e.g. tablets), eReaders (the software used to display eBooks), eBooks (the books themselves), the content within the eBooks, and the channels through which eBooks are distributed to their users.

Coordinating these components can be challenging. To be broadly used, an eReader must function on iOS and many variants of Android devices, while an eBook must be usable in

multiple eReaders. Most eReaders conform to some version of the EPUB standard (Wikipedia, 2018; IDPF, 2018), but the affordances offered to the end user can vary in look, feel, and functionality. Creating an eBook requires an authoring tool, for which there are many choices with varying capabilities, and often requires significant development outside of the authoring tool. Publishing and distributing an eBook can also require a considerable level of effort in making technical and financial arrangements.

As things stand, a would-be creator of an educational or training eBook that ventures beyond static content must understand and be able to code in HTML5 and a range of additional technologies and software packages. A remarkably similar situation was faced by early developers of web-based eLearning, and, as happened in that case, we anticipate that the eBook will become a widely used platform for adaptive and immersive training through a convergence of standards and tools. We believe that the *Personalized eBooks for Learning* (PeBL) project presented in this paper represents a significant step towards this convergence.

2 The PeBL Project

PeBL is rooted in a three year IEEE Industry Connections activity (IEEE, 2016) (chaired by one of the authors, John Costa) that examined the capabilities of eBooks to support location-based adaptivity, xAPI-based results reporting and analytics (ADL xAPI, 2018), virtual laboratories, and various other pedagogical affordances. To further this work, the US Advanced Distributed Learning (ADL) initiative funded the PeBL project (led by one of the authors, Elliot Robson) to create a public specification and open source reference implementation as part of its Total Learning Architecture (TLA) research (ADL TLA, 2018). The PeBL specification and other information are available at www.peblproject.org, and, as of the writing of this paper, an IEEE Learning Technology Standards Committee (IEEE LTSC) study group chaired by the first author of this paper is considering the development of recommended practices and guides based on the work of the PeBL project as well as the work of commercial vendors.

2.1 PeBL Functionality

Commercial-grade eBooks and eReaders conform to the EPUB standard, which was developed by the International Digital Publisher Forum (IDPF) that is now operating as the Publishing Business group within the World Wide Web Consortium (W3C). The current version is EPUB 3.1.

In broad strokes, EPUB 3.1 defines a method for encapsulating HTML5 content in a package that includes book-like organization and navigation. The standard defines a menu of end-user functionality that an EPUB-conformant eReader should support. Features such as displaying a table of contents, enabling readers to highlight text, and support for re-flowable text are on the standard menu and are supported by most commercial eReaders. These are features that are needed for the primary current use case for eBooks, which is providing downloadable, mobile access to standard print-based materials, e.g. to any content that can be put into PDF format. However, many features needed to support training and educational applications are either not supported by many eReaders or not part of the EPUB standard at all. Some of these, which are addressed by the PeBL project, include the ability to:

- Report activities via the Experience API (ADL xAPI, 2018)
- Display rich analytics to instructors and to students, as in the work of Brusilovsky and others (Brusilovsky, Chavan, & Farzan, 2004) (Brusilovsky, et al., 2016) (Hsiao, Bakalov, Brusilovsky, & König-Ries, 2011)
- Embed interactive elements ranging from quizzes to simulations and intelligent tutors
- Adapt content to user preferences and to professed or demonstrated prior knowledge
- Create learning that is location and motion aware
- Enable instructors to push content or alter content in a learner's eBooks
- Enable learners to communicate with each other and to add share notes in context
- Enable learners to connect with networks of experts in real time or asynchronously
- Make as much of the above available as is possible when devices are offline

2.2 The PeBL Architecture and Specification

The PeBL architecture is defined via an open specification available at https://peblproject.com/specification.html. PeBL functionality is defined in the specification and implemented via modularized *extensions*. These extensions are individually inserted into a book and can be mixed and matched in any combination in a given PeBL book. Extensions are characterized as belonging to tiers that progressively improve and expand on the user experience as tier numbers increase. Tier 1 requires a fully EPUB 3 conformant eReader. Tier 2 requires supporting cloud infrastructure. Tier 3 requires a PeBL conformant eReader (that can communicate with external systems). The following diagram (Figure 1) shows the three tiers.

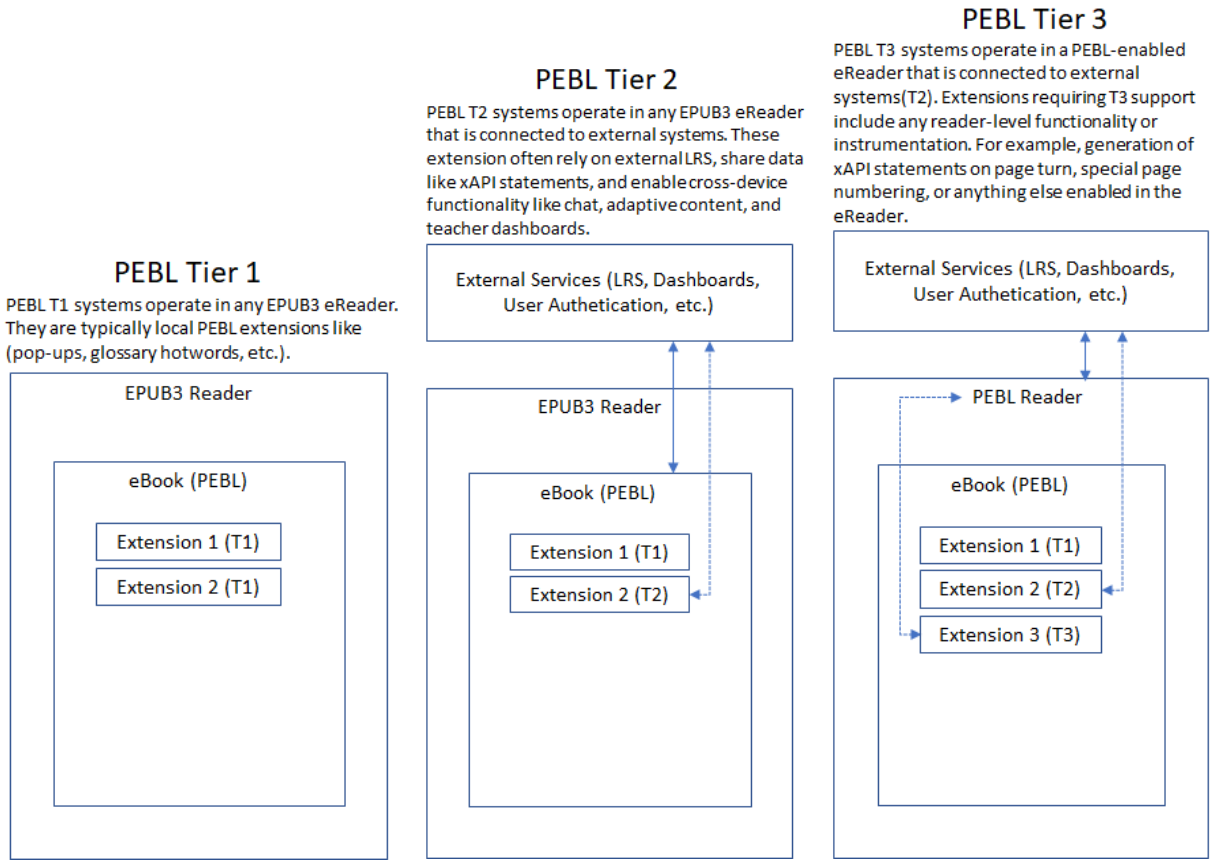

Figure 1: PeBL tiers

The approach taken by PeBL embeds as much functionality as possible in the books rather than the eReader or cloud-based services. This lessens dependence on eReaders but does not eliminate it entirely. Although a PeBL book should ideally work on any EPUB 3 conformant eReader, in practice each eReader works differently and has different features, so extensions must still be tailored to targeted eReaders. Current efforts in the PeBL project are creating a modular design template for extensions in which each extension gracefully degrades from its full implementation to a simpler version with less features in accordance with the level of support detected in the user's eReader.

2.3 Additional Components

A PeBL book requires an eReader, but starting with Tier 2, PeBL books also require a Learning Record Store (ADL LRS, 2018) for capturing xAPI-generated statements. Tier 2 and 3 books in practice may also require an instance of some system for storing relevant knowledge, skills and abilities (competencies) such as the open source *Competency and Skills System (CaSS)* (Eduworks Corporation, 2018). A competency management system such as CaSS is also needed

to manage learning goals and learner profiles, and for computing and (securely and privately) storing the state of each learner with respect to competencies.

Tier 2 and 3 components are required for instantiating a wide range of adaptive behaviors and for generating and displaying analytics, which, even without any advanced interactivity or adaptivity, sets PeBL books aside from ordinary eBooks. For this reason, the PeBL project has developed both in-book and external dashboards and analytics displays that may also be considered additional PeBL components. The dashboards have two versions, one tailored to students and one to teachers. These are described in more detail in Section *3.2 Analytics Dashboards*.

Finally, the PeBL project has developed a library / bookshelf. Like those available on platforms such as the Kindle, a bookshelf stores and can be used to launch downloaded PeBL books with standard bookmarking functionality. A PeBL extension can provide user access control within a PeBL book if it is not handled at the reader level. Another PeBL extension, in conjunction with the EPUB 3 CFI (canonical fragment identifier) specification, provides enables cross-links between book, so a book in the bookshelf can be launched from within a different book.

3 PeBL in Practice

The best way to illustrate the affordances of the PeBL platform is to examine how PeBL has been used. In this paper we describe two use cases, one that was part of a larger research project carried out by the ADL and one that was supported by the eXtension Foundation, a not-for-profit organization that provides professional development for 15,000 university agricultural extension professionals in the United States.

3.1 A Cybersecurity Book

The PeBL project is supported by ADL funds dedicated to developing a *Total Learning Architecture* (TLA) that includes specifications and enabling technologies, of which PeBL is both. Evaluations of the year 1 prototype have been conducted as part of the ADL 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.. This instantiation included multiple sources of training content in areas of cybersecurity, ranging from publicly available videos (e.g. YouTube) to a PeBL book, a cyber range, and an immersive game.

The prototype PeBL book used in this test addressed the topic of social engineering. One of its features was *multi-level content*, illustrated in Figure 2 on the next page, in which a user could toggle back and forth between basic content and detailed explanations. This is relatively simple yet pedagogically useful functionality that is facilitated by a tier 1 PeBL extension and that can be taken one step further using a tier 2 extension that enables the book to select the content to display based on a learner's mastery level and preferences. The PeBL reader and library were leveraged to securely host, deliver, and track additional TLA learning materials in a variety of formats including PDF, PowerPoint, Microsoft Word, and public web pages.

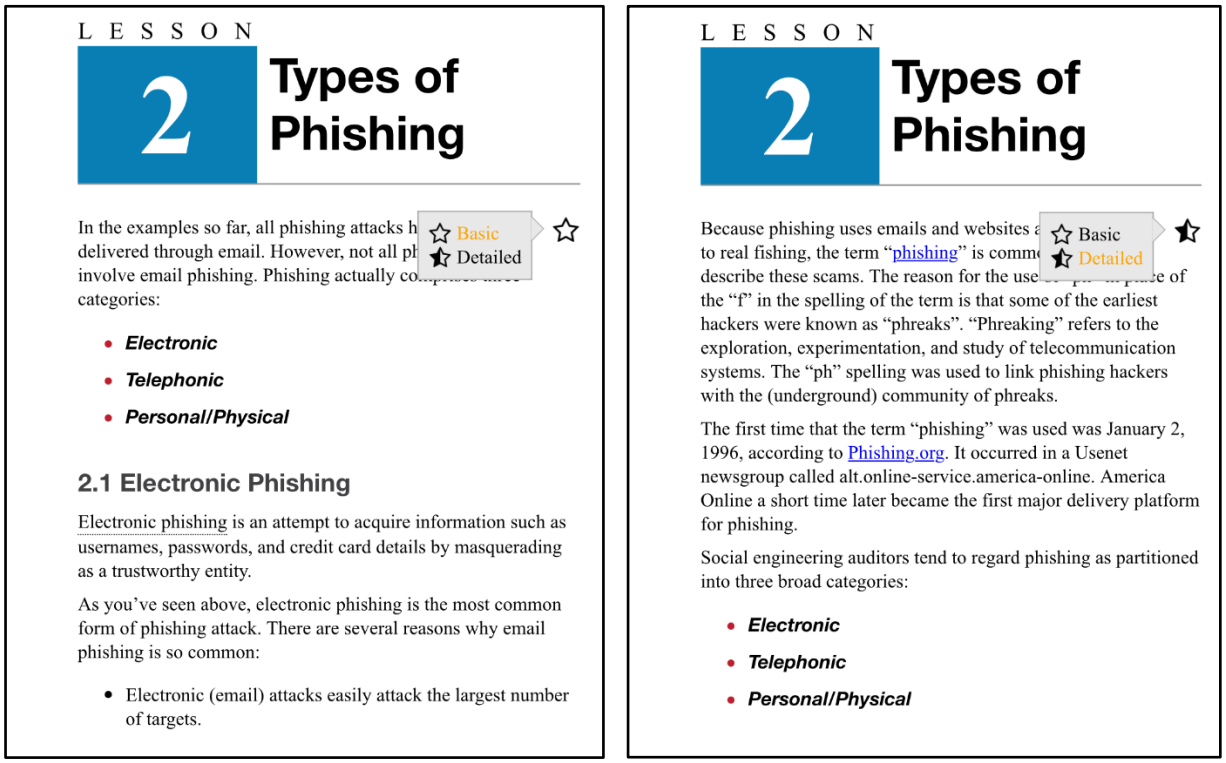

Figure 2: Multi-level Content Switching

Another set of tier 2 PeBL features involves multi-user interactions. These require connectivity and are based on the ability of PeBL extensions to read and write shared data from a Learning Record Store (LRS). In the cybersecurity book, learners were able to open chat windows at specific locations in the book and use these windows to participate in threaded discussions with other learners to discuss the content at those locations. These discussions implement a feature that is commonly supported by learning management systems (LMS), but unlike in the typical LMS or MOOC, the PeBL version does not require the learner to switch out of the content into a separate chat window or application.

Although not implemented in the prototype cybersecurity PeBL book, the PeBL specification supports many other types of tier 3 multi-user interactions, ranging from embedding Google™ docs, spreadsheets, presentations, and drawings in eBooks to encapsulating applications running on a server, such as a multi-player simulation or game. These are termed "widgets" in PeBL terminology. Unlike extensions, widgets involve applications that cannot be implemented natively in JavaScript and HTML 5 and must therefore be embedded in in an HTML frame. The next use case will illustrate the use of widgets, but we will first cover another key feature of PeBL books, namely *analytics dashboards*.

3.2 Analytics Dashboards

An important feature of PeBL is its ability to gather data about a learner's interactions with a PeBL book. A predecessor to the PeBL project was a proof of concept of xAPI and EPUB 3 integration developed under the IEEE Actionable Data Book activity. It included xAPI reporting and the ability to graphically display xAPI events (Segall, Costa, & Chuang, 2015). PeBL adds more robust and complete reporting and LRS extensions that provide local LRS functionality, using the HTML5 local storage feature (W3Schools, 2018) to cache data and then synchronize it with a shared LRS when a book is online. The type and granularity of activities reported is up to the PeBL extension and the designer or author of the book. Standard reporting, supported by existing PeBL extensions, includes data on what content a learner has viewed, how long they spent viewing it, and on the results of any interactions such as quizzes or other assessments embedded in the book.

These data are collated into two types of analytics dashboards, one that provides instructors with an overview of activity within a class and one that can be added to each version of the book. Either can be presented on a web page or within ta book. The former can be used by instructors to manage a class and to personalize the eBook experience for individual students. The latter shows each learner their progress and, in more sophisticated versions, can be used to show students where they stand in relation to the class. This has been shown to improve learning outcomes (Brusilovsky, et al., 2016; Hsiao, Bakalov, Brusilovsky, & König-Ries, 2011).

In addition to activity data, PeBL dashboards can provide views into the knowledge, skills, abilities, and learning objectives that learners have mastered. These data are derived from the integration between PeBL and CaSS, which is significant because PeBL books may be used in conjunction with other learning systems and are intended to be just one component in a larger

learning ecosystem. In the TLA prototype discussed in Section 3.1, for example, mastery data came from a cyber range, a serious game, and other forms of training.

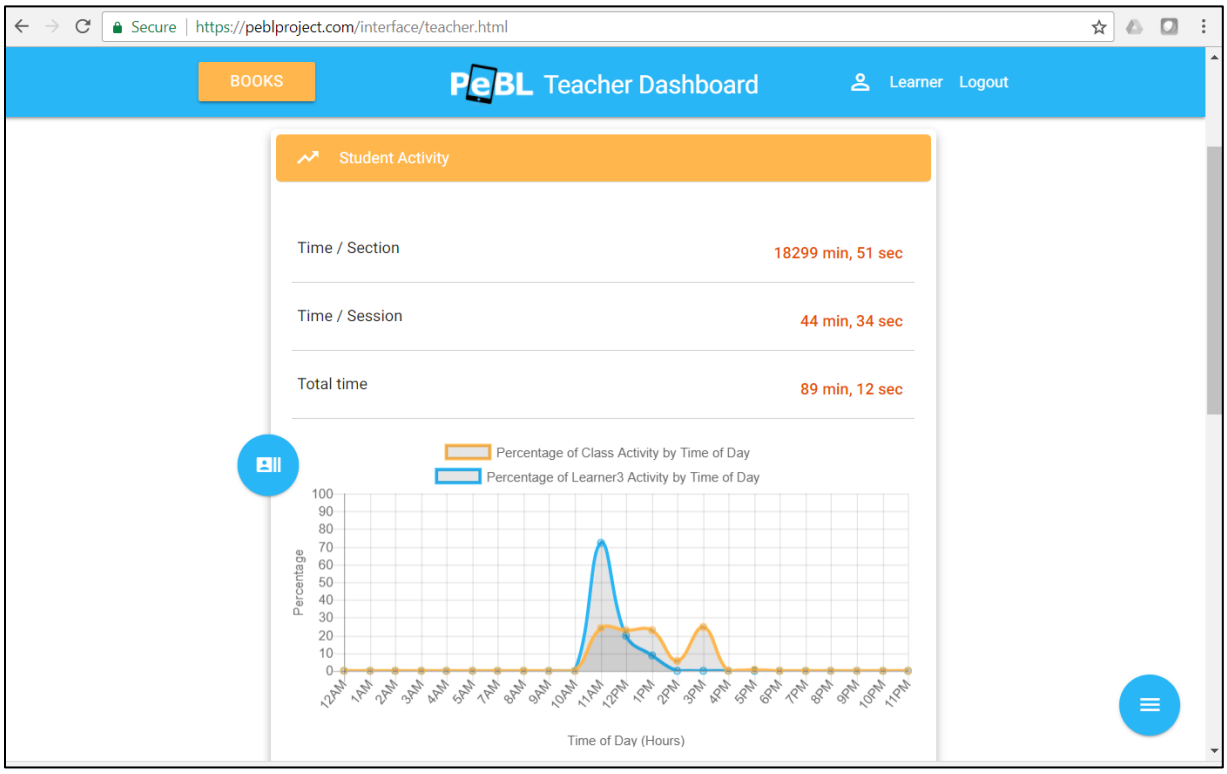

Figure 3: Example of a PeBL instructor dashboard

3.3 A PeBL Field Notebook

A second product created by the PeBL project is a field notebook designed to be used as a repository of resources and information for agriculture extension professionals while they are working in the field. The book was created in 2017 for the eXtension Foundation to support dissemination of the results of agricultural research generated by academic institutions to producers (e.g., farmers), distributors, and consumers. The product is now deployed to field eXtension agents and is undergoing trials.

The primary objective of the eXtension field notebook is to help field agents find, store, and share resource documents and to enable them to contact and get advice from experts with relevant expertise. To support the interactions between users and a network of experts, the field notebook includes the ability for experts to replace or add existing content using a PeBL application programming interface (API). In this case, the permitted content is restricted to resource links, and the content can only be added to specialized elements in the field notebook

(called *topic cards*), but the API is more general. This capability pairs with the ability of a book to display different pre-loaded content to support both push- and pull-based adaptivity.

The eXtension book also implements several components that rely on widgets. As described earlier, widgets are interfaces to external systems or client-side applications that are embedded within a PeBL book. Various methods can be used to embed widgets, including the W3C Widget standard and HTML iFrames. Widgets in the eXtension book include a cloud-based *Ask an Expert* system that routes questions directly to designated experts selected on the basis of topic and location, and an advanced search function that searches for people, organizations, content, or resources in an enterprise content repository.

Finally, the eXtension PeBL book allows users to record and store notes, true to its designation as a "notebook". Notes are contextualized to a location in the book and can be shared with other users. They can be recorded as annotations to user-highlighted passages or as topic cards. Notes, bookmarks, and annotations are transmitted as xAPI statements and stored in the PeBL LRS, allowing greater interoperability with other learning systems and flexibility in reuse of data.

4 The PeBL Roadmap

Even at this early stage, it is apparent that PeBL holds great promise as a platform for mobile, interactive, data-driven learning. The PeBL project has been able to develop extensions that implement a wide range of Tier 1 and Tier 2 functionality with relatively little effort and has been able to create PeBL books using off-the-shelf authoring tools such as Adobe InDesign®. The use of these tools, together with separation of content from the extensions that display it, has reduced the technical demands of maintaining PeBL books to a level on a par with maintaining web sites or standard eLearning. This level is acceptable to potential customers, including several US Government agencies that are considering PeBL as a path to migrating their existing training to interactive mobile platforms.

As an example, the *discussion extension* is designed so that authors can insert them into the body of their lessons with no programming experience whatsoever. Setting up a context-dependent discussion requires the author to add only three items to a paragraph: [he word *Discussion*, the question being asked, and a discussion ID number (provided). The PeBL discussion extension does all the heavy lifting. It creates the chat box, inserts the question text, and applies the discussion ID to every chat entry typed by students.

The next major step is developing full-featured authoring tools that do not demand knowledge of JavaScript™, CSS, and other languages in the HTML5 programming framework and that can be used to publish cross-reader, cross-platform tier 1 and tier 2 PeBL books. These books must be usable with a variety of off-the-shelf, freely available, commercial eReaders on Android, iOS, Windows, and Macintosh based devices. They must implement xAPI-based reporting; multi-user interactions; instructor- and user-driven as well as competency-based adaptation; graceful degradation of functions when switching to offline operation; and various types of analytics dashboards. Design work has already begun in this direction. Once authoring tools are in place, we believe that PeBL, which is a fully open source project, will become a significant pathway for migrating and developing mobile learning that successfully implements multiple instructional approaches ranging from didactic learning to problem-based and collaborative learning rooted in Constructivist (Janassen, Peck, & Wilson, 1999) and Connectivist theories (Chatti, Jarke, & Quix, 2010) of learning.

4.1 Security and Privacy

Security and privacy are increasingly important considerations for any educational or training technology. The PeBL specification supports a range of policies but mandates encryption of data generated by the user; requires the ability of PeBL books to create user accounts local to an eReader; and stipulates that books should adhere following high-level principles:

- Data at rest is encrypted.
- Transmission of records is made over SSL/TLS.
- Each user's data is stored separately.
- Each user's data is not accessible to other users.
- A book can access stored data only through a controlled API.
- Personally Identifiable Information (PII) must be managed in accordance with regulations and local needs and, in general, is not stored locally with the identifiable information present.

4.2 Beyond ELearning

PeBL can be used to transform existing desktop eLearning into interactive, data-rich, mobile learning and to add features that take full advantage of functionality that cloud-connected tablet devices offer, ranging from multi-user interactions to analytics and content adaptivity. In addition, PeBL permits eBooks to be integrated with simulations, intelligent tutoring systems (ITS), virtual and augmented reality (AR/VR), Live-Virtual-Constructive (LVC) environments, and other more complex forms of learning activities. Tier 3 PeBL extensions enable these types of training to be embedded directly in PeBL books and to be controlled from PeBL books. In the resulting PeBL books, the more static aspects can guide learners and provide information, reference materials, and context at multiple levels of depth, while the dynamic and more advanced aspects can provide adaptivity, social interaction, and analytics and serve as a framework in which learners can engage with simulations, ITS, AR/VR, serious games, and other adaptive immersive systems. This is the direction we see PeBL taking, although we anticipate that many use cases and implementations will focus on more traditional training and education.

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