Serious Games as edX MOOC Activities

Manuel Freire, Ángel del Blanco, Baltasar Fernández-Manjón,
Universidad Complutense de Madrid, Facultad de Informática
C/ Profesor García Santesmases, s/n. 28040 Madrid, Spain
{manuel.freire, angel.dba, balta}@fdi.ucm.es

***Abstract*—Massive Online Open Courses are in the process of radically changing the use of technology in education, as measured both by the number of enrolled students and the level of academic excellence of the institutions that are driving their adoption. Typically, online learning management systems have relied on simple questionnaires for feedback and evaluation. On the other hand, MOOC platforms such as EDX have, from the onset, provided a great flexibility in this regard, providing peer grading and several examples of highly interactive activities such as hands-on simulations. This paper explores the integration of serious games as a new type of MOOC activity, providing increased engagement and a valuable source of learning analytics. The inclusion of serious games has implications for both courses and games. Due to the diversity of existing serious game and MOOC platforms, we focus on the specific case of integrating EADVENTURE games into EDX.**

Keywords—MOOCs; serious games; e-learning; learning analytics

I. INTRODUCTION

Massive Online Open Courses(MOOCs)are a radical departure from traditional eLearning systems[1]. MOOCs are open to vast amounts of users: leading MOOC platforms such as COURSERA, IVERSITY and EDX have millions of enrolled students, and their numbers are growing quickly. All three platforms offer free courses, open to anyone with internet access. The result is a highly competitive environment where platforms, courses and e-learning strategies are under constant evolution.

The development of web technologies has also increased the depth and scope of learning activities that can be accessed online. For instance, several EDX courses feature rich browser-based simulations and programming environments, with outputs that can be automatically graded. Despite these tools, student retention is generally low – it is typical to see less than 10% of initially-registered students graduating from courses[2]. We propose the inclusion of a new type of activity with proven positive effects on immersion and engagement: Serious Games (SGs), defined as those whose primary goal is not recreational but educational. Most students in the core demographics [3] for MOOCs can be presumed to be players of video games [4], and SGs have been seen to be effective at increasing both content retention and learner engagement [5], [6], while slowly gaining acceptance into online learning systems. SG scan provide a supportive narrative context [7] missing from bare simulations, making user decisions have consequences beyond simple grades. From the point of view of instructors, SGs can also provide rich feedback in the form of interaction data that can be used for detailed analytics.

However, to fully realize these advantages, SGs would need to be integrated into MOOCs as first-class citizens, communicating and interacting with other MOOC modules such as grading, feedback and analytics. An example of external SG use from within a MOOC can be found in [8]. This type of loose coupling requires substantial instructor intervention to bridge the gaps between the tools.

The main goal of this paper is to analyze the issues involved in achieving tighter SG integration within MOOCs. A first challenge is posed by the number and diversity of both SGs and MOOCs. We therefore narrow down the discussion to an EDX module for the integration of EADVENTURE SGs into EDX courses. We have chosen to work on EDX due to its open-source nature [9], as opposed to COURSERA or UDACITY's closed-source model. Conversely, EADVENTURE [10] is an SG platform developed by the author's research group at the Universidad Complutense de Madrid.

The paper is structured as follows: Section II describes the EDX approach to MOOC modularity. Section III addresses the integration of EADVENTURE SGs into EDX courses, while Section IV describes a preliminary version of the EADVENTURE module, highlighting authoring, assessment and gamification. Finally, Section V provides a brief discussion of our experience during this integration, and an overview of future work.

II. EDX AND MODULAR MOOCS: XBLOCKS AND INSIGHT

From a technical point of view, the main difference between MOOCs and traditional Learning Management Systems (LMSs) such as MOODLE, SAKAI or BLACKBOARD is that of scale. While scale imposes certain requirements on physical hardware, its main effect is that of limiting instructor intervention to a bare minimum, forcing grading and community support (for example, moderation of student forums)to be either highly automated or performed by the students themselves. Current practices for SG integration into traditional LMSs can still be followed as long as the games require no course staff intervention for either moderation or evaluation.

EDX was jointly launched by MIT and Harvard University in 2012, and has quickly gained support from other leading academic institutions. As of October 2013, more than 29 institutions from over the world were offering over 90 courses, a number that is quickly growing. Adoption by other institutions has benefited by the fact that the EDX platform has, from the

The following sponsors have partially supported this work: the Spanish Ministry of Science and Innovation (grant no. TIN2010-21735-C02-02); the European Commission, through the Lifelong Learning Programme (projects "SEGAN Network of Excellence in Serious Games" - 519332-LLP-1-2011-1-PT-KA3-KA3NW and "CHERMUG" - 519023-LLP-1-2011-1-UK-KA3-KA3MP) and the 7th Framework Programme (project "GALA - Network of Excellence in Serious Games" - FP7-ICT-2009-5-258169); and the Regional Government of Madrid (eMadrid Network - S2009/TIC-1650).

onset, fully embraced open-source practices. The platform comprises both an LMS, which provides course delivery and tracking, and a Course Management System (CMS), known as Studio, for course authoring and management.

Significant effort has gone into making EDX modular and welcoming of rich activities. For example, EDX has support for exercises from the LON-CAPA [11] repository. These can range from simple multiple-choice questions to complex simulations with circuit simulators or molecule editors. EDX also contains a module which provides partial integration for a well-known protein folding game, FOLD.IT [12].In general, successful integration of a new activity into a MOOC entails three different user scenarios involving different roles: a) authoring, b) runtime, and c) analytics. During authoring, course authors configure the activity, its presentation, and how it relates to other course components. Runtime support allows students to access the activity as part of their normal coursework. Finally, analytics support allows student interactions to be analyzed by course authors in both individual and aggregated forms to notify students about their performance. EDX conflates authoring and presentation into EDX activity modules, and currently has built-in LMS support for a very limited global course progress analytics. The development of XBLOCKS (for authoring and presentation) and INSIGHTS (analytics) addresses the need for increased modularity.

A. Modular activities in EDX

In general, in EDX each activity type is managed by an internally-executed module, which defines its presentation and behavior. These modules can be relatively high-level and collaborate with each other – for example, a simple sequencing module is in charge of presenting a set of components (lowest-level course components) as tabs; while all LON-CAPA components will be managed by yet another complex module.

Hosting activities internally is considerably simpler, from an architectural point of view, than executing activities externally. Compared to the Learning Tools Interoperability (LTI) approach, activity modules avoid the need for external servers to host the content, and communications from and to the activity are radically simplified. The downside is the requirement for careful vetting of externally-supplied code. This can be addressed in two ways: by making extensions easy to inspect for correctness, or by falling back to strict isolation as external applications. While the use of a highly readable programming language (Python) to implement most of EDX (including modules) certainly facilitates code inspection, EDX has also developed an LTI-compliant module, which should provide the best of both worlds. A third route would have been to provide support for Sharable Content Object Reference Model (SCORM)[13] packages, widely used in other LMSs. SCORM allows the aggregation of self-contained web-based activities following the Learning Object paradigm, ranging from a single activity to complete courses with units, lessons, and activity sequences, with limited access to storage using a well-defined data model (termed CMI). However, SCORM places severe limits on delivery and tracking for new learning scenarios, and supporting the standard would require complex mappings between its data model and that of EDX.

To simplify additional module development and testing and improve internal isolation, EDX is introducing a new module specification: XBLOCKS [14]. Existing modules will be progressively phased out as the specification matures. Unlike current modules, the execution environment for XBLOCKS is well-defined, allowing reuse (and hosting) in external web applications. This will allow XBLOCKS to be tested independently of each other, resulting in greatly simplified quality assurance. XBlock-hosting environments must provide authentication, scoped storage, URL mappings, and analytics[15]. Additionally, different environments can request different views for different usage scenarios. For example, Studio, the EDX course-authoring environment, will require XBLOCKS to provide a separate authoring view, in addition to the standard view used by the LMS environment when the components are actually being shown to students. The peer-grading workflow environment can require yet another view, to present to students when grading other students. XBLOCKS, are, in turn, in charge of maintaining their own state, providing the different views expected by their environments, handling external requests (for example, user interaction with their rendered fragments) and internal events (triggered, for instance, when instructors decide to re-grade a problem), and interacting with their parent and/or children XBLOCKS.

B. INSIGHTS as modular analytics

EDX is pursuing a parallel approach to modular analytics with the development of *INSIGHTS*, defined as self-contained plugins that can be added, removed and reused easily, using an "app store" metaphor [16]. These analytics modules need not be tied to particular XBLOCKS, although this would appear to offer a natural way to add analytics to custom XBLOCK developments.

As the Insights specification matures, adding an Insights module to an EDX deployment will grant it access to its collected data and to incoming course events. The module can then process events, perform queries on available data sources, and schedule complex query execution or large report genera-

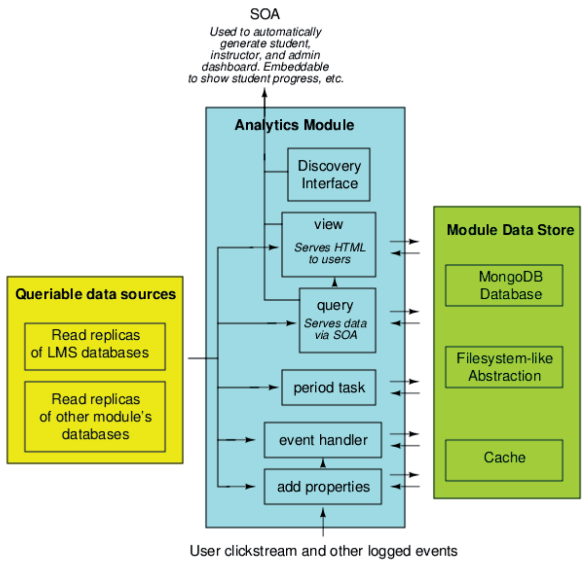

Fig 1.: EDX's proposed analytics architecture. Analytics modules, called *INSIGHTS*, encapsulate queries and resulting views. Image from the EDX documentation [9].

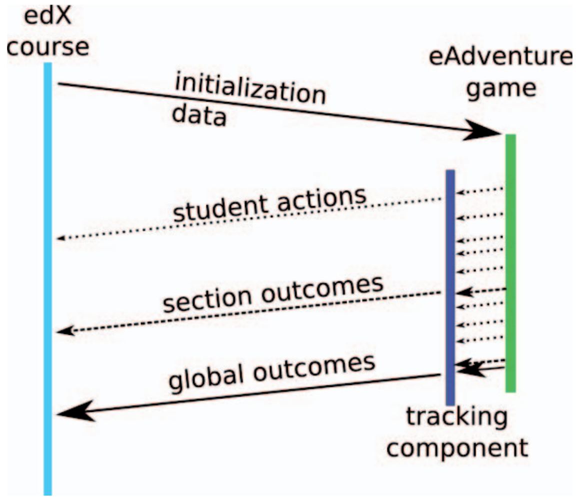

Fig 2.: Communication between EDX module and EADVENTURE. Events are organized in a hierarchical fashion. EADVENTURE's tracking component is in charge of filtering and aggregating low-level events (dashed lines) to the desired level of detail.

tion. INSIGHTScan also generate and advertise views for sion into the LMS's analytics dashboards. Fig. 1 provides an overview of the main functionalities of INSIGHTS and how they interact with available data stores and sources. Depending on their importance and execution speeds, INSIGHTS are intended to fall into one of three tiers: real-time student progress, slightly higher-latency teaching analytics, and low-priority experimental analytics, such as those that would be run for post-course analysis or research projects.

III. EADVENTURE AS A COURSE ACTIVITY

The EADVENTURE platform has been in continuous development at the Universidad Complutense de Madrid since 2004. EADVENTURE includes a fully-featured game editor, intended to allow non-technical users to create and modify their own SGs. At any time, authors can export their games for particular platforms and content packagings. For instance, the same game can be exported as a stand-alone desktop application or as web-hosted Java applet in standardized (e.g. SCORM [10]) or platform-dependent format (e.g. LAMS), intended to be run from a conventional LMS (e.g. MOODLE), providing different alternatives at the time of integrating the games [17].

EADVENTURE games support sophisticated educational assessment beyond simple output of game completion and final grades. In particular, they can respond to initial conditions (as reported by their host environment), and generate detailed reports based on educationally significant game actions. Using the game editor, authors can create rules that map game states to report outputs. The output can be then attached to the student's profile, using SCORM CMI or other mechanisms. Integration with LAMS[18] is described in [19], demonstrating collaboration with the hosting environment in a complex learning-design scenario. EDX has limited support for learning design, with the possibility of specifying conditions that restrict access to specific course parts until satisfied.

Integrating EADVENTURE SGs as EDX activities can be performed at several levels of granularity:

A. Minimal integration

An EADVENTURE game can take the place of a traditional exercise, reporting back degree of completion, degree of correctness (or score), and the total time spent. No information is shared except at the end of the game, and this information is similar to that of any other EDX problem. This corresponds to sending only the "global outcomes" in Fig. 2.

B. Multi-level integration

An EADVENTURE game can be decomposed into a series of scenes or chapters, each of which can be considered a sub-activity. Results (completion, score, time spent) can then be reported for each. This requires careful thought by the game designers (or exporters) in order to create meaningful subdivisions. Larger divisions may have smaller subdivisions, leading to a multi-level assessment. From the point of view of EDX, a single level of decomposition is similar to handling whole sequence of exercise results instead of those of a single exercise. On the other hand, EADVENTURE games can be designed to allow each student to follow a different path. This kind of complex learning design is currently not handled by EDX.

In Fig. 2, multilevel integration would entail the sending of repeated "section outcomes", in addition to a single global outcome.

C. Low-level integration

At the lowest level, individual actions within the game are reported as a constant stream of events. However, this requires considerable support from the learning analytics side to make sense of the incoming data. For best results, game designers should collaborate with course designers to specify what to send and how to interpret it. This requires a custom analytics module to process EADVENTURE evaluation data - that is, a

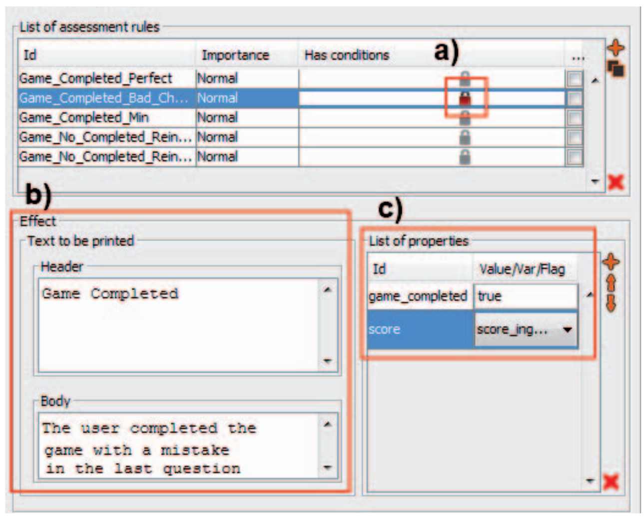

Fig 3.: EADVENTURE's assessment profile panel. For the selected assessment rule (a) is a condition over the game state that triggers the rule, while (b) is the information included in the assessment report, and (c) are the pair attribute-value to be send to the LMS-MOOC.

custom EADVENTURE INSIGHT.

Fig. 2 illustrates the communication between the tracking component of EADVENTURE and the EDX host. The mappings that describe what game events should trigger updates to the student profile, and how events should be aggregated into higher-level updates, are encapsulated in each exportation profile. Fig. 3 illustrates the process of defining such a mapping.

IV. CREATING AN EADVENTURE MODULE

We have implemented proof-of-concept EADVENTURE EDX integration module for the first two integration levels identified in Section III. The module works correctly within the test environment, but has not yet been deployed into an actual MOOC. This section describes its design and implementation, and describes how a higher-level integration can be achieved.

A. Authoring and run-time

The EADVENTURE editor supports multiple exportation target types. Once the game has been exported for HTML distribution, it can be displayed from within any browser. During game export, users can specify how and what the game will communicate with the hosting web-page; in our case, the EDX LMS (runtime scenario).

From within the EDX CMS, we then configure a client-side tracking component (see Fig. 4) to manage communication between the guest EADVENTURE game and the host environment. A server-side component services the requests generated by the client-side component, behaving, from the point of view of EDX, just as any other module. The EADVENTURE integration module supports both authoring and run-time modes. During authoring, the tracking component is configured to communicate correctly with the hosted game; for example, the number of game scenes and the maximum achievable progress level for each must be configured. This is then saved as part of the course. Fig. 4 is a screenshot of the configuration process.

Once the course is deployed in the LMS, the same two components receive user actions and track student progress, committing results into the same databases that are used to track progress in other EDX activities, plus a specific database dedicated to the additional information generated during EADVENTURE play.

B. Evaluation perspective

Since the development of EDX'S INSIGHTS is still in the early phases, we provide the exact same EDX analytics as other modules – that is, aggregated total score in the corresponding activity. However, all activity is being logged and is readily available for further analysis in the database, within a separate table dedicated to EADVENTURE games.

Additionally, EADVENTURE games can send activity streams to external, non-EDX servers. Fig. 5 contains a heatmap generated from user activity in an EADVENTURE game, collected by GLEANER [20]. As INSIGHTS matures, we would like to integrate more of GLEANER's visualizations into EDX as INSIGHTS modules.

The massive nature of MOOCs rules out any kind of personalized grading of game traces on the part of instructors. An interesting possibility is that of peer-review for serious games: students who complete a game would be requested to evaluate other student's playthroughs, analyzing their decisions (and, in the process, comparing them with their own). Our current integration does not support this feature, as it would require providing students with the type of analytics that are currently only available to instructors.

C. Gamification perspective

Gamification refers to the inclusion of game-like characteristics, such as scores or completion badges, to non-game material. It is the result of the observation that game-players are often ready to invest significant efforts to challenge each other (and themselves) in achieving the highest possible scores and game mastery. In the form of certificates and badges for course-completion, it is present to some degree in all main MOOCs. In the specific case of EADVENTURE games, we plan to include a small dose of external gamification:whenever students finish a course, they will be presented with a small histogram representing the scores (assumed to be equivalent to "game progress") of all other students. Their particular score is

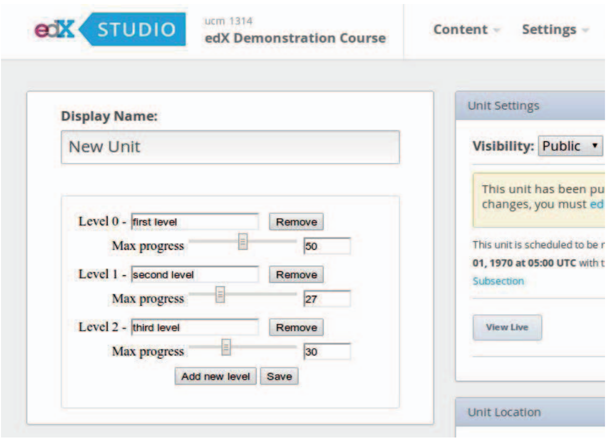

Fig 4.: Configuring the EDX EADVENTURE client-side tracking component. This view allows level settings to be adjusted.

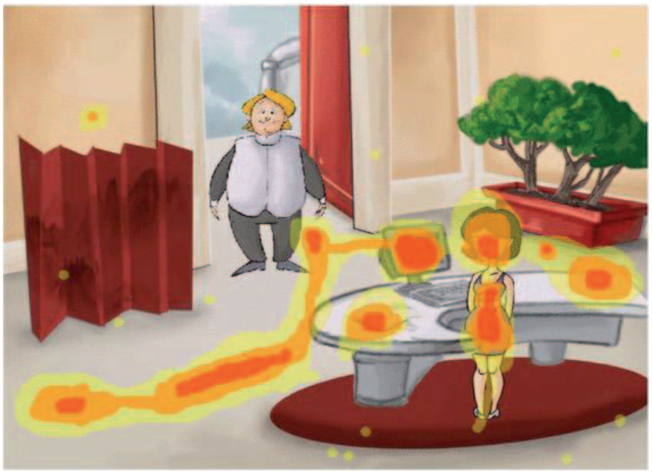

Fig 5.: Example heatmap for an EADVENTURE game, from [20].

highlighted in this same histogram, allowing quick visual self-assessment.

V. CONCLUSSIONS

The integration of serious games into MOOCs can provide significant value for both. EDX's solid academic credentials and open-source nature makes it an especially interesting integration target, providing highly interactive content that can engage students and them to assess and apply their knowledge in an immersive scenario. This is not without challenges, as rich interaction is harder to evaluate than other, more traditional, alternatives. The present paper explores some of the issues that must be addressed in order to achieve this integration, attempting to chart this territory for future systems.

We have developed proof-of-concept modules test content integration, and have surveyed the current analytics capabilities of EDX. Although this proves the technical feasibility of integrating EADVENTURE games into EDX, we still lack experimental validation of actual user and instructor acceptance. At the time of writing, EDX is still under heavy development, and the APIs for both XBLOCKS and INSIGHTS are not yet considered stable. As the APIs stabilize, we will continue development, with the goal of delivering a fully-functional EDX export option (including both modules) in future versions of the EADVENTURE platform.

ACKNOWLEDGMENT

The authors thank María Díaz Calvo, Daniel López Carreras and Ricardo J. Carrión Beltrán for their exploratory work on EADVENTURE and XBlocks, and the rest of the e-UCM research group.

REFERENCES

[1] D. M. Norris, "7 things you should know about first-generation learning analytics," 2011. [Online]. Available: http://www.educause.edu/ir/library/pdf/ELI7079.pdf. [Accessed: 20-Jan-2014].

[2] D. Seaton, Y. Bergner, I. Chuang, P. Mitros, and D. Pritchard, "Towards Real-Time Analytics in MOOCs," ceur-ws.org, 2013. [Online]. Available: http://ceur-ws.org/Vol-985/paper3.pdf. [Accessed: 20-Jan-2014].

[3] L. Breslow, D. Pritchard, J. DeBoer, G. Stump, A. Ho, and D. Seaton, "Studying learning in the worldwide classroom: research into edX's first MOOC," Res. Pract. Assess., vol. 8, no. Summer, pp. 13–25, 2013.

[4] Entertainment Software Association, "Essential facts about the computer and video game industry," E3, 2013. [Online]. Available: http://www.theesa.com/facts/pdfs/ESA_EF_2013.pdf. [Accessed: 20-Jan-2014].

[5] S. Arnab, R. Berta, J. Earp, S. De Freitas, M. Popescu, M. Romero, I. Stanescu, and M. Usart, "Framing the Adoption of Serious Games in Formal Education," Electron. J. e-Learning, vol. 10, no. 2, pp. 159–171, 2012.

[6] M. D. Dickey, "Engaging by Design: How Engagement Strategies in Popular Computer and Video Games Can Inform Instructional Design," Educ. Technol. Res. Dev., vol. 53, no. 2, pp. 67–83, 2005.

[7] M. D. Dickey, "Game Design Narrative for Learning: Appropriating Adventure Game Design Narrative Devices and Techniques for the Design of Interactive Learning Environments," Educ. Technol. Res. Dev., vol. 54, no. 3, pp. 245–263, 2006.

[8] M. Romero and M. Usart, "Serious Games Integration in an Entrepreneurship Massive Online Open Course (MOOC)," in Serious Games Development and Applications, vol. 8101, Springer Berlin Heidelberg, 2013, pp. 212–225.

[9] EdX Project, "EdX development webpage," 2013. [Online]. Available: http://code.edx.org/. [Accessed: 20-Jan-2014].

[10] Á. del Blanco, Á. Serrano-Laguna, I. Martínez-Ortiz, B. Fernández-Manjón, and I. A. Stanescu, "INTEGRATING SERIOUS GAMES INTO E-LEARNING PLATFORMS: PRESENT AND FUTURE," in 9th International Scientific Conference of eLearning and Software for Education, 2013, no. i.

[11] G. Kortemeyer, W. Bauer, D. Kashy, E. Kashy, and C. Speier, "The LearningOnline Network with CAPA Initiative," in 31st Annual Frontiers in Education Conference. Impact on Engineering and Science Education. Conference Proceedings (Cat. No.01CH37193), 2001, p. F2D–F23.

[12] S. Cooper, F. Khatib, A. Treuille, J. Barbero, J. Lee, M. Beenen, A. Leaver-Fay, D. Baker, Z. Popović, and F. Players, "Predicting protein structures with a multiplayer online game.," Nature, vol. 466, no. 7307, pp. 756–60, Aug. 2010.

[13] ADL, "Advanced Distributed Learning Sharable Content Object Reference Model (ADL-SCORM) 2004 v4," 2009.

[14] IMS Global Consortium, "IMS Learning Tools Interoperability, Version 1.1 Final Specification," 2012.

[15] Edx Doc Team, "XBlocks — XBlock 0.3 documentation." [Online]. Available: https://xblock.readthedocs.org/en/latest/guide/xblock.html. [Accessed: 20-Jan-2014].

[16] Edx Doc Team, "EdX Insights documentation," 2013. [Online]. Available: http://github.com/edx/insights. [Accessed: 20-Jan-2014].

[17] Á. del Blanco, E. J. Marchiori, J. Torrente, I. Martínez-Ortiz, and B. Fernández-Manjón, "Using e-learning standards in educational video games," Comput. Stand. Interfaces, vol. 36, no. 1, pp. 178–187, Nov. 2013.

[18] J. Dalziel, "Implementing learning design: The learning activity management system (LAMS)," 2003. [Online]. Available: http://www.lamsfoundation.org/CD0506/html/resource/whitepapers/ASCILITE2003 Dalzie Final.pdf. [Accessed: 10-Nov-2013].

[19] A. Del Blanco and J. Torrente, "Towards the generalization of Game-Based learning: Integrating educational video games in LAMS," in 10th International Conference on Advanced Learning Technologies, 2010, pp. 5–7.

[20] Á. Serrano, E. J. Marchiori, Á. del Blanco, J. Torrente, and B. Fernández-manjón, "A framework to improve evaluation in educational games," in *Global Engineering Education Conference (EDUCON), 2012 IEEE*, 2012, pp. 1–8.