



# Application of Learning Analytics in educational videogames<sup>☆</sup>



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## ABSTRACT

Assessment of learning contents, learning progress and learning gain is essential in all learning experiences. New technologies promote the use of new types of contents like educational videogames. They are highly interactive compared to more traditional activities and they can be a powerful source of data for all forms of assessment. In this paper, we discuss how to apply Learning Analytics (LA) with assessment purposes, studying how students interact with games. One of the biggest barriers for this approach is the variety of videogames, with many genres and types. This makes it difficult to create a comprehensive LA model for educational games that can be generally applied. In order to maintain manageable costs, we propose a two-step approach to apply LA: we first identify simple generic traces and reports that could be applied to any kind of game, and then build game-specific assessment rules based on combinations of these generic traces. This process aims to achieve a balance between the complexity and reusability of the approach, resulting in more scalable LA models for game-based learning. We also test this approach in two preliminary case studies where we explore the use of these techniques to cover different forms of assessment.

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## 1. Introduction

Teachers of all educational levels and areas of knowledge are increasingly using new technologies to improve their teaching practices. Among others, they are starting to use Game-Based Learning (GBL) activities to explore new ways to educate their students. Studies like [1–3] support that videogame features such as high interactivity, engagement and challenge can impact the learning processes positively, both by increasing students' motivation and academic performance. The latest Horizon Reports from 2012 to 2013 [4,5] on emerging educational technologies include GBL as a technology that is almost ready for massive adoption.

In turn, assessment processes are central in educational contexts: instructional designers must assure the validity of their methods, instructors need to track the progress of the students in order to provide support and to measure the acquisition of knowledge or skills for formal grading, usually involving the use of some sort of test [6].

All these forms of assessment play a major role in current research on game-based learning. As an innovative form of content,

games should undergo validation processes. Furthermore, it would be necessary to develop new forms of assessment especially devised for videogames, given that they present content in new ways and that much more student interaction data is produced with video games than with less interactive contents. In addition, the engaging interactive nature of videogames leads naturally to authentic learning tasks [7], which suggests that videogames may even be used as an assessment tool that can be better than traditional exercises [8]. However, assessment is not thoroughly contemplated in many GBL initiatives, leading to errors and lack of results. It also difficulties adoption because assessment is key in formal education, and having gaps in this area creates distrust in teachers and policy makers alike [9].

In order to increase the adoption of GBL approaches, it is necessary to create reliable assessment systems for videogames that are easy to use, that facilitate the different forms of assessment (e.g. formative, summative, etc.) and that leverage the interactive features of videogames in a cost-effective way.

Among the different perspectives from which this task can be approached, in this work we focus on the potential (and challenges) of applying the techniques typically used in Learning Analytics [10] and Game Analytics [11,12] in GBL scenarios. Learning Analytics addresses the processing and visualization of data collected from interaction and navigation through educational contents. In some cases, Learning Analytics techniques are used to predict future students' outcomes in different educational goals.

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For that purpose, Learning Analytics is usually implemented as a combination of several technologies and techniques, like data mining, Web-Analytics [13] and Business Intelligence [14]. In turn, the discipline of Game Analytics spans a set of techniques widely used by the game development industry to better understand how users play their games, find errors and improve the game play experience. For the sake of simplicity, along this paper we will simply use the term “Learning Analytics”, while we may be referring to either Learning Analytics, Game Analytics or a combination of both techniques.

However, transferring these techniques to the specific challenges of assessment in GBL scenarios poses unique challenges: the potentially available data for applying Learning Analytics techniques is much bigger because interaction is very intense during a gameplay session, and the existing constructs from game analytics techniques are often game-specific (which reduces scalability) and do not cover the special requirements of educational contexts.

In order to facilitate the convergence, in this work we present a two-step approach to define a scalable Learning Analytics System that can support different forms of assessment in GBL activities. The two steps are driven by the technical requirements of scalability, uniformity and reuse of efforts: we start by defining a small and easily treatable set of generic traces, and then build higher level assessment rules by combining those generic traces, resulting in game-specific traces that do not require a full redesign of the assessment system for each individual game.

The paper is structured as follows: first, we describe the general context of this work, the challenges and the requirements. Second, we define a set of basic universal game-agnostic traces that are easily applied, gathered and processed. Then, we describe the second step, in which game-specific assessment rules can be constructed by combining the basic traces. We then exemplify the use of these steps through two exploratory case studies, in which we studied how the system would support the different types of assessment required. Finally we summarize our conclusions about the advantages and disadvantages of our approach and outline some future lines of work.

## 2. Games, assessment and Learning Analytics

The term assessment is often used to describe different activities and therefore it is necessary to clarify its meaning along this paper. In the literature, it is common to make the distinction between assessment *of* learning (e.g. for certification) and assessment *for* learning (e.g. to provide support for students during the learning experience) [15]. A third form is typically contemplated, namely assessment *as* learning (e.g. self-evaluation and peer-evaluation), although in this work we have focused on the first two concepts (assessment *of/for* learning).

In addition, when using innovative forms of content, an additional previous step is required: the assessment of the content artifact itself, in order to find design and implementation issues that may hinder the learning experience. The next subsections briefly discuss the forms of assessment considered in this work, along with their relationship with Learning Analytics.

### 2.1. Assessment of the game artifact

When new instructional materials are created, the assessment of their appropriateness is important, given that the extra effort required for their adoption must be justified. Indeed, most instructional design approaches are based on the generic ADDIE model [16], where the E stands for Evaluation.

Such evaluations may vary, ranging from basic “student acceptance” evaluations to complex multi-stage evaluation procedures,

but as a rule of thumb the more expensive the content is, the more rigorous the evaluation should be. One of the first steps is evaluating the overall suitability of the game for the target audience and context. In this sense, de Freitas and Oliver proposed four distinct dimensions to evaluate the suitability of a specific game design, focusing respectively on *pedagogic considerations*, the *learner specification*, the *context* and the *mode of representation* [17]. However, when the proposed game is a new development, basic software validation techniques are typically used, usually in the form of formative evaluations. In some scenarios with strict formal requirements, further evaluations are typically conducted to validate the appropriateness of the game formally (e.g. by comparing their effect in a randomized trial).

When the instructional material is as complex as an educational game, testing and validating the games before their application is a significant challenge. First, making sure that a game is engaging and fun is an elusive process, since these abstract constructs are difficult to measure, and usually require applying invasive techniques. In addition, the usability of games in general and serious games in particular is complex and time-consuming due to the specific traits of this family of applications [18]. Sim, MacFarlane and Read also explored the challenges associated with understanding when an educational game is successfully performing its function [19], and Eladhari and Olilla have explored the complexity of the problem of evaluating interactive games in general [20].

From this situation, it seems that there is a lack of universal evaluation/validation procedures that can be applied to any game to detect issues and identify solutions. In this context, we believe that it may be possible to leverage the use of Learning Analytics to support the first part of the process (detecting spots where the game misbehaves or where the users get lost) so that game designers can try new solutions to avoid those issues.

### 2.2. Assessment of learning

Assessment with games has been traditionally dealt with by conducting debriefing sessions or regular written tests after the activity. In this sense, the information generated within the game activity is not always considered for assessment. Sometimes the reason is that the videogame lacks the necessary tools to facilitate collecting and extracting game play data. However, some games include features that can be useful for assessment, like Questions and Answers (Q&A), where the game calculates a final score based on students’ answers. More rarely the games implement an ad-hoc assessment system and the results are shown as feedback (during game play or at the end) to the student.

Q&A is the natural translation of traditional exams into a game, yet this mechanism is not fully compatible with the nature of the games. Prompting the student to answer questions very frequently can break the game flow, putting engagement and motivation at risk [21]. This has resulted in a growing search for stealth assessment approaches [22,23] that evaluate the performance of the student transparently.

We expect that the Learning Analytics approach, when applied to serious games, can represent a powerful mechanism to conduct stealth assessment procedures.

### 2.3. Assessment for learning

Assessment for learning typically focuses on conducting early assessment not with the purpose of grading, but with the purpose of providing adequate instructional scaffolding to the students [24]. Indeed, early formative assessment is a keystone in any educational process that aims to support the students as they learn, and some authors argue that scaffolding and formative assessment are essentially the same thing [25].

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