Using learning analytics to analyze learning outcomes in a serious game

Ángel Serrano Laguna
Complutense University of Madrid
Department of Software Engineering and Artificial Intelligence
Complutense University of Madrid
Madrid, Spain
angel.serrano@fdi.ucm.es

Abstract— **Although serious games are proven educational tools in many educational domains, they lack reliable, automated and repeatable methodologies to measure their effectiveness: what do players know after playing a serious game? Did they learn with it? Literature research shows that the vast majority of serious games are formally assessed through questionnaires, which strikes a stark contrast with current trends in the video game industry. Commercial videogames have been learning from their players through Game Analytics for years, using non-disruptive game tracking. We propose a methodology to assess serious games effectiveness using non-disruptive in-game tracking. The methodology proposes a design pattern that structures the delivery of educational goals within the game. This structure also allows inferring learning outcomes for each individual player, which, when aggregated, would determine the effectiveness of the serious game. We have tested this methodology with a serious game that was played by 320 students. The proposed methodology allowed us to infer players' learning outcomes and assess game effectiveness and to spot issues in the game design.**

Keywords—serious games; learning outcomes; learning analytics; game design;

I. Introduction

A serious game is a video game designed with purposes beyond pure entertainment [1]. Serious games have become proven educational tools in recent years: they are used across many domains with multiple goals and formats, and their acceptance and effectiveness is almost always positive [2], [3]. Traditionally, a large percentage of serious games has been both developed and deployed by educational researchers, limiting their scope and reach. This trend is starting to change. Nowadays, widespread use of Virtual Learning Environments (VLE) allows for the application of serious games in unprecedented scales. To reach their full potential, serious games should adopt the latest advances in education and commercial videogames [4].

On-line education has increased exponentially in recent years, and many students now learn through Internet-connected devices. This vastly increases the amount of educational data available for analysis. Disciplines such as Learning Analytics (LA) or Educational Data Mining (EDM) study the patterns inside students' interactions to better understand the underlying learning processes [5], [6]. This knowledge can be used by different stakeholders with diverse purposes: from university administrators calculating dropout rates in each class, to teachers identifying students at risk of school failure [7].

Serious games (and video games in general) are particularly well suited for data analysis. Their highly interactive nature, based on a constant loop of user input followed by game feedback, pose them as rich sources of interaction data. These interactions can be later analyzed to explore how users play, and, in the case of serious games, understand how users learn.

The video game industry has been performing these type of analysis in commercial games for years, via Game Analytics (GA) [8]. One of the main uses of GA is to measure balance in gameplay: a balanced video game is one that keeps its players in the flow zone, a state where the player feels challenged by the game, but neither bored nor frustrated [9]. GA helps to locate parts inside games where players get stuck or quit; and moments where a game's mechanics or internal rules fall short. GA also provides clues on how to fix these problems.

Commercial video games usually collect data from their players in a non-disruptive way, with tracking systems that go unnoticed by the players [10]. However, according to the literature [11], the main method to assess any aspect of a serious game is the use of questionnaires filled by players. There is a clear need to combine the emerging disciplines of LA and EDM with the non-disruptive techniques of GA to provide reliable, automated and repeatable assessment for serious games.

Serious game assessment can focus on many results, such as usability, engagement or motivation. However, learning outcomes is the result most stakeholders want to obtain from serious games [12]. Learning outcomes are also the most frequent result assessed in recent serious games [11], and some authors even believe that such outcomes could be used to replace standardized tests [13]. However, multiple issues with serious games must first be addressed. One of them is the lack of methods to assess serious games effectiveness [14]: teachers, lecturers and policy-makers need guarantees that serious games are effective enough to be used in the classroom.

In this regard, the use of GA techniques with serious games can provide stakeholders with objective, reliable data.

We propose a methodology to infer learning outcomes and serious games effectiveness based on non-disruptive tracking. The methodology targets two different phases in the life of a serious game: 1) its design and implementation, where we propose a game-design pattern to shape the delivery of the educational content throughout the game, and 2) its validation and deployment, where we propose an analysis, based on the game-design pattern, to infer learning outcomes and game effectiveness.

II. PROPOSED METHODOLOGY

Our methodology pursues two goals: 1) to ease the measurement of serious game learning outcomes and 2) to provide a systematic way to assess the effectiveness of serious games as a whole. To achieve these goals, our approach covers the complete lifecycle of the serious game (Figure 1). The process starts in the design phase, where the learning goals and the target population are the basis to create a learning and game design. These designs combined are used to implement the game, which is then validated in a formative evaluation with a sample of the target population. This process is repeated until the game is fully validated. Then, the game is ready to be used by the target population (deployment).
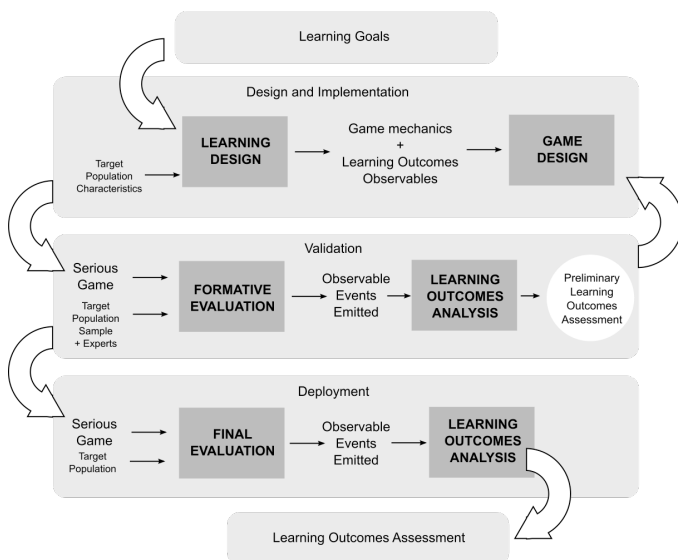

Fig 1. Serious game design and deployment process, with learning outcomes assessment

[1] G. Liu, L. Fu, A. V. Rode, and V. S. J. Craig, *Water Droplet Motion Control on Superhydrophobic Surfaces: Exploiting the Wenzel-to-Cassie Transition*, vol. 27, no. 6. 2011.

[2] K. Squire, "Video games in education. International Journal of Intelligent," *Simulations and Gaming*, vol. 2, no. 1, pp. 49–62, 2003.

[3] T. M. Connolly, E. a. Boyle, E. MacArthur, T. Hainey, and J. M. Boyle, "A systematic literature review of empirical evidence on computer games and serious games," *Comput. Educ.*, vol. 59, no. 2, pp. 661–686, 2012.

[4] C. S. Loh, Y. Sheng, and D. Ifenthaler, "Serious Games Analytics: Theoretical Framework," in *Serious Games Analytics*, Cham: Springer International Publishing, 2015, pp. 3–29.

[5] T. Elias, "Learning Analytics : Definitions , Processes and Potential," *Learning*, p. 23, 2011.

[6] M. A. Chatti, A. L. Dyckhoff, U. Schroeder, and H. Thüs, "A reference model for learning analytics," *Int. J. Technol. Enhanc. Learn.*, vol. 4, no. 5/6, pp. 318–331, 2012.

[7] R. Ferguson, "The state of learning analytics in 2012: a review and future challenges," 2012.

[8] M. S. El-Nasr, A. Drachen, and A. Canossa, *Game Analytics: Maximizing the Value of Player Data*. Springer, 2013.

[9] J. Chen, "Flow in games (and everything else)," *Commun. ACM*, vol. 50, no. 4, p. 31, 2007.

[10] S. Santhosh and M. Vaden, "Telemetry and Analytics Best Practices and Lessons Learned," in *Game Analytics: Maximizing the Value of Player Data*, 2013, pp. 85–109.

[11] A. Calderón and M. Ruiz, "A systematic literature review on serious games evaluation: An application to software project management," *Comput. Educ.*, vol. 87, pp. 396–422, Sep. 2015.

[12] A. All, E. P. Nuñez Castellar, and J. Van Looy, "Towards a conceptual framework for assessing the effectiveness of digital game-based learning," *Comput. Educ.*, vol. 88, pp. 29–37, Apr. 2015.

[13] L. A. Annetta, "The 'I's' have it: A framework for serious educational game design.," *Review of General Psychology*, vol. 14, no. 2. pp. 105–112, 2010.

[14] J. A. Vargas, L. García-Mundo, M. Genero, and M. Piattini, "A Systematic Mapping Study on Serious Game Quality," in *Proceedings of the 18th International Conference on Evaluation and Assessment in Software Engineering, EASE 2014*, 2014, pp. 1–10.