Serious games: A journey from research to application

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***Abstract*— This paper presents our perspective on serious games, covering relevant aspects of the current situation and what we consider are the key elements to be developed over the next few years. Serious games have undergone a long journey from niche research to application in real settings, coming closer to the generalization of games in mainstream education. We describe some of the lines of research we consider more relevant for completing this journey.**

Keywords—serious games, educational games

I. INTRODUCTION

The idea of using games (and more specifically, digital games) in education is not new. In the early 80's, when both personal computers and video games were still in their infancy, visionaries such as Malone were able to glimpse the huge impact that the new medium could have in education [1]–[3], and throughout the 90's, the idea remained in the academic field, with different isolated initiatives implemented by pioneering development teams (e.g. [4]–[7]).

However, it was in the first years of the new millennium, as the entertainment videogame industry experienced an exponential growth, that a new generation of academic researchers gathered those ideas and pushed them into the Technology-Enhanced Learning (TEL) arena. Ten years ago, "game-based learning" and "serious games" works appeared with increasing frequency in the leading TEL conferences and journals, slowly at first and often drawing discussions about whether using in education games was a good idea at all.

In this context of rapid growth, the last four years have represented a golden age for research in serious games: TEL conferences routinely include sessions focused solely on serious games, it is rare to find issues of major TEL journals that do not include any mentions of games, and new dedicated conferences and journals have become established. And another very clear indicator: the first ICT Work Programme in the newest (2014) European Union Research and Innovation Programme, called Horizon 2020 (H2020), contemplates a specific call focused exclusively on "non-leisure games" with a total budget of EUR 17 million [8].

In this work, we start with a quick look at what has made games so exciting from an academic perspective, their increased acceptance over the last few years and, most of all, the rapidly emerging lines of research and main expected outputs for the next years.

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II. SERIOUS GAMES: IT'S NOT ONLY ABOUT FUN

Educators have long identified flow states (in which concentration and engagement are maximized) as a desired state for motivated learners [9]. While schools struggle in an attempt to even minimally engage their students, modern videogames have thrived as an entertainment industry focused on knowing how to make engaging products that capture the attentions of players of all ages and backgrounds [10]. However, serious games are about much more than "if kids play instead of doing homework, let's administer the homework via games".

The potential of serious games goes deeper that this simplified conception. When game designers reflect on what makes games fun, it is often related to their short feedback cycles and their capacity to offer a challenge that is always one step beyond the ability of the player [11], a concept very closely tied with the Vygotsky's Zone of Proximal Development [12]. In short, games are fun because they tap our innate instinct towards acquiring new skills and perceiving our own progress [11].

In addition, games provide exciting environments for collaboration or competition, both relevant features in education, and their combination of realism and fantasy can be the ideal vehicle to provide situated or "authentic" learning scenarios [13].

III. ACCEPTANCE OF SERIOUS GAMES

In spite of these potential advantages, a significant amount of academic discussion originally focused on whether serious games had any real educational potential, with both proponents and detractors [14]. Remarkably, the excessive development cost for serious games made it very difficult to create good serious games ready to be deployed in classrooms, and this raised issues related to the lack of solid comparable results obtained with adequate research methods.

Recently, however, more solid results showing measurable educational gains through game-based learning [15] moved the debate forward, prompting researchers to explore emerging application models and develop new strategies that aim to improve their practical application and potential.

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A. Authoring and engineering

Creating educational games is a costly and complex process that hinders their application in real settings, placing a burden on their widespread adoption. This aspect has been addressed with the creation of new game authoring environments specifically oriented to education that simplify the creation and maintenance of the games, while facilitating the inclusion of educationally-oriented characteristics such as in-game evaluation. These authoring platforms are usually focused on specific game genres (e.g. platforms, narrative, etc). For example, eAdventure (http:// e-adventure.e-ucm.es) provides a graphical interface oriented towards educators which allows the creation of point-and-click adventure games and story-based game-like simulations without any programming.

Besides authoring environments, serious-game development methodologies that systematize the creation of new games are also needed. Detailed methodologies, which could be domain dependent, could help to simplify the game development making it more predictable [16]. Such methodologies typically describe what are the steps and which experts should be involved in the design, development and testing of the games.

B. Adaptive games

The most basic adaptive learning structures require three elements. First, a mechanism to gather information about the student must be present. This information can be gathered through questionnaires, knowledge tests, or observation of the student's interactions with the system. From these observations we can construct the second required element, a user model for each individual student that stores information about their preferences and personal characteristics. Finally, the third element is the choice of one or more strategies to adapt the learning experience, by selecting an appropriate piece of content and/or by adapting the content itself [17].

Educational games present a leap forward in terms of how we gather information about the students and how we adapt the contents. Games are complex software products, in which the players are continuously interacting with the system, triggering changes and receiving constant feedback.

Regarding the process of gathering information about the student, interaction data provides a wealth of opportunities to gain insight into how each student is interacting with the game, potentially resulting in very detailed data sets. For example, a game engine may track the transitions and in-game events and generate detailed interaction reports [18].

While turning these reports into usable learner models remains an open challenge (as we will discuss in the next section) once we have a detailed user model and we need to make an adaptation of the learning experience, games can also play an important role. If we focus the adaptation on selecting an appropriate piece of content, games can be one of the alternative pieces for students that prefer alternative communication modalities rather than text or even videos. And if we focus in fine-grained content modifications, the highly interactive nature of games makes them a very relevant medium to include rich adaptations.

This potential has been explored in different initiatives with different approaches. Games created with e-Adventure can perform the full adaptation cycle, since they are designed to gather and report relevant state transitions that can be used for assessment and/or gathering information about the user. In addition, the games can be designed with different pathways supporting fine-grained adaptations [17].

Similarly, the FP7-funded 80Days project also leveraged games to create and refine user models, and from this information managed to dynamically adapt the behavior of the game to suit the needs of each specific student [19].

C. Assessment

We consider that assessment is a key issue to convert serious games into mainstream educational content. In many cases, even when serious games are used for teaching, evaluation continues to be done in a traditional pen-and-paper format. As integrating games in the learning flow requires an extra effort, we consider that this effort should pay off in terms of better learning and assessment.

This situation can be improved by including in-game modules for the analysis and evaluation of user interactions that can be used to automatically assess the user's learning progress [20]. This information can be used with different purposes such as user self-evaluation or as a formal assessment of the user knowledge.

D. Standardization

Games are usually very dependent of technology and platform. However, there are multiple competing technology standards in the industry. Most currently-deployed games have been developed using proprietary technologies (e.g. Adobe Flash) creating many problems for reuse, maintenance and deployment in new portable devices. Even though there is no short-term solution for these incompatibilities, the appearance of new environments that provide automatic deployment for different platforms (e.g. Unity3D) and the emergence of new cross-platforms technologies such as HTML5 are expected to mitigate that problem.

In addition to cross-platform concerns, most games are usually deployed as standalone applications with very limited communication (if any) with the rest of the educational infrastructure. These aspects have been partially addressed by applying the lessons learnt with existing e-learning content packing standards such as SCORM [21]. That is, games can be treated as a special case of educational learning objects.

E. Experimental validation

Connolly et al. [22] identified a large number of papers (7392) about entertainment games, games for learning and serious games, confirming that there has been a surge of interest in the field. Nevertheless, the vast majority of these papers speculated about the potential of games in learning, described how a game was designed or discussed theoretical issues underlying the design of games. Most papers did not include empirical evidence concerning positive impacts and outcomes of games with respect to learning and engagement. Currently, growing numbers of researchers are addressing

such concerns by providing data on impacts and outcomes of educational game-play as an integral part of their publications.

In addition, the thorough validation of a serious game is a complex task, with validation requirements covering adequate transfer of knowledge, return on investment and usability [24].

Even if games have moved from niche applications domains (e.g. military, healthcare) to more widespread use (e.g. languages, history), the number of success-stories that are backed by solid formal evaluations is still relatively low. Lessons learned from these experimental validations are very helpful when applying the research results into real settings. Previous successful experiences are especially useful for addressing aspects such as scalability or deployment.

The research on serious games has recently moved towards a more rigorous approach to study design, a very relevant requisite for improved acceptance by stakeholders [25].

IV. Emerging research

After their consolidation in the last four years, serious games research is healthier than ever. Having dispelled (most) doubts about their potential effectiveness, it has become gradually easier to innovate and promote new lines of research and well funded pilot experiences.

Indeed, the NMC 2013 Horizon Report highlights serious games as one of the trends ready for true adoption in the classroom over the next 2-3 years [26]. This timeline is aligned with the expected peak in the development of the projects funded by the H2020 Call on Gaming Technologies and Gamification [8].

Therefore, in the course of the next four years, the challenge is two-fold: to facilitate the transition towards the classroom and to imagine the features of the next generation of serious games. The following subsections detail some of the lines of research we consider more relevant.

A. Game analytics, learning Analytics and stealth assessment

As mentioned in the previous section, games can produce very detailed interaction reports. Indeed, so detailed, that transforming them into usable data is a significant challenge. Games can produce big data sets that contain detailed information on how each player has been interacting with the game.

While there are significant challenges in treating these data, recent advances in Game Analytics [27] have allowed game developers to gain insight into how players interact with their games. This trend coincides with the growing body of academic research in web-based Learning Analytics, partially fuelled by the emergence of massive online courses that can yield significantly larger data sets [26].

Performing large-scale analysis of big data sets to infer learning and assessment information is another technology identified by the Horizon Report for short-term adoption. The crossroads of serious games and learning analytics is therefore remarkably unique: we find it much harder to make sense of the data sets generated by games but, due to their sheer size, data-mining and clustering techniques may bring relevant insight into how players interact with them.

Within the EU GALA Network of Excellence and the eMadrid network, serious games and learning analytics are some of the key emerging areas of research, as represented by the GLEANER project [28]. A long term goal is that all that data could be used for obtaining a better assessment of the user knowledge using non-obtrusive methods in what is also referred to as stealth assessment.

B. Stealth assessment

Stealth assessment can be seamlessly woven into the fabric of the instructional environment to support learning of important content and key competences. This represents a quiet, yet powerful process in which learner performance data are continuously gathered during the course of playing/learning and inferences are made about the level of relevant competences. This kind of assessment is intended to support learning and maintain educational flow, and remove (or reduce) test anxiety, while not sacrificing validity and reliability. Its main goal is to eventually blur the limits between assessment and learning [29].

C. Serious games and accessibility

As education is a universal right, the use of serious games in education requires that games should be universally accessible. This includes people with physical or cognitive disabilities. Accessibility is an open issue, because it is not usually covered even in entertainment games; and the costs of creating accessible educational games is frequently not affordable.

Instead of trying to add accessibility features to pre-existing games, we consider that research should move towards developing new methodologies and game authoring tools with built-in accessibility features that simplify the creation of accessible videogames and increase the awareness of the game development community regarding accessibility. In eAdventure we have included several accessibility-related features intended to ease the creation of accessible games for certain kinds of physical disabilities (e.g. limited vision).

D. Mobile gaming, new devices

The gaming arena rapidly changing with a new generation of casual users that plays mostly using mobile devices. Serious games should take advantage of this new situation to simplify adoption in schools and formal education where the Bring Your Own Device (BYOD) approach is becoming increasingly common [30].

BYOD creates new scenarios where games need to be deployed in a more heterogeneous environment (e.g. tablets, smartphones) that are not completely under the control of the educational institution, thus requiring additional support to track the use and effectiveness of the games.

V. Conclusions

Serious games started as an interesting idea, remained a niche area of research for almost two decades and have

exploded in the last decade. Nevertheless, regardless the numbers of ‘‘educational” video games that are marketed, these are not the games children tend to prefer [31]. Many student surveys demonstrate their preference towards technology usage, but largely neglect the motives and considerations for playing video games. Therefore, capturing students’ attention and interest and keeping them engaged is of primary importance to the video game designer. More specifically, serious games designers must have more information about their final consumers to improve the effectiveness and engagement of their games.

However, within that timeframe, these last four years have been very positive, representing a transition from a situation of very high expectations but low actual results towards a situation of widespread acceptance and exploration of future technologies and models.

The area has greatly matured in this period, with more advanced technologies, an increasing focus on quality and, most of all, the emergence of tangible results in formal experiments. This has reduced the barriers preventing acceptance, and the future of serious games is exciting. As mentioned earlier, the Horizon Report expects serious games to finalize their transition towards the classroom in the next two years, and the number of initiatives (publicly of privately funded) promoting new forms of serious games is growing rapidly, and will likely yield a new generation of innovative applications. As a network of research groups, eMadrid is in a unique position to channel these transitions, and it is our responsibility to make them happen.

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