# Applying learning analytics to simplify serious games deployment in the classroom

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*Abstract*—**In this paper we present our approach to introduce educational videogames as class exercises in face-to-face education. The main objective is to simplify teachers' task when using games by providing real-time information of the actual students' use of the games while in the classroom. The approach is based on defining the educational goals for the exercise/game precisely, designing a game that captures these goals, establishing relations between game interactions and educational goals and finally, create data capturing and visualizations of the relevant information to support the teacher. We applied this approach to a real case study, creating an educational videogame about the XML markup language that substituted the usual exercises in a Web Technologies class. This was tested with 34 computer science students with positive and promising results.**

***Keywords—game based learning; serious games; learning analytics; classroom exercises; visualizations;***

## I. INTRODUCTION

Almost all teachers use practical exercises in their classes to help their students to consolidate knowledge and acquire new skills. While resolving exercises, students have to apply theoretical knowledge to solve specific problems demonstrating their understanding and identifying possible doubts or misunderstandings. This is especially important in scientific disciplines, where practice is fundamental in the learning process.

However, it is very complex to know what is actually happening in the classroom and it is even more complex when interactive content such as games or simulations is used. When teachers want to keep track of the progress of their class, among other things, they must monitor how students resolve classroom exercises. But the efforts to keep a complete view of students' progression in a normal class escalate exponentially as the number of students and exercises grow. In most cases, teachers only obtain a partial view that force them to rely on a large extent in objective evaluation (i.e. written exams) to assess their students [1]

Nowadays, new trends in education –combined with the emergence of new technologies– plead in favor of changing the number and type of interactions between teachers and students. One of these trends is Learning Analytics (LA), a discipline based on the analysis of student interactions with on-line educational resources to improve the educational process. LA results and metrics can benefit –with highly different purposes– teachers, organizations and students themselves [2].

Ideas behind LA can help teachers to keep track of the students –on a daily basis– through classroom exercises. We only need to satisfy two requirements: first, the students must resolve exercises using a connected device, so the device can communicate back the resolution process; and second, a LA system must listen to this user data, analyze it and present it to the teacher in a meaningful way.

We think that educational videogames can be a good tool to create "connected" classroom exercises. Many authors point out their qualities for education, and videogames are a perfect place to experiment and practice skills [3], which fulfills the needs for classroom exercises.

In this paper, we present our approach to successfully deploy videogames as classroom exercises whose results are automatically visualized by the teacher. This paper is structured as follows: first, we refer some related works that connects students in the classroom with the teacher using some device. Second, we define the steps of our approach and then we detail a study case in which we applied it. Finally, we discuss some results and conclusions.

## II. RELATED WORK

The authors in [4] describe the process to prepare an observed pedagogical experiment defining two phases: the pre-experiment and the experiment. The first phase include two steps: the collection configuration and the structure configuration (which data to collect and how these data structures for subsequent analysis); and the second phase includes four steps: collect, structure, analyse and represent/visualize (the analysis process). In this work, authors define "observable factors" as the low-level interactions that students perform with an e-learning system. A set of rules convert these low-level observable factors into more high-level events, with a particular meaning inside the educational context. This is approach is somehow general, and is intended to analyse abstract interactions of students. We want to extend this idea making educational goals the foundations of the process, and students assessment its result.

Authors in [5] refer one of the first examples of students using connected devices to participate in the classroom, back in 1996. Students answered direct questions using a palm-top computer (which had a full QWERTY keyboard and LCD screen) connected to a central computer. With this system, teachers presented test questions about the course content itself but also about students' feelings and opinions of the class. This idea evolved parallel to the technology, and new research appeared with improved hardware, e.g. using RF clickers [6] or mobile phones [7].

One of the disadvantages of this type of systems is that the interaction students perform is limited, since in most cases answers consist of selecting an option or writing a word. Thus, both data for analysis and results' visualizations are also limited. On the other hand, videogames are usually complex highly interactive applications that can present hundreds of situations and options to students therefore the data extracted can be much richer.

But simplify teacher task when using interactive content is essential for the acceptance of new technologies. Therefore, it is necessary to provide simple and useful LA data, such as visualizations. Some authors are trying to avoid the pure statistical graphs and reports, looking for more depurated views [8], and authors in [9] propose that LA visualizations should follow the idea of "goal oriented visualization".

We take all the ideas presented in this section to define our approach.

## III. USING VIDEOGAMES AS CLASSROOM EXERCISES

We define an approach whose final purpose is to show teachers the results of their students in classroom exercises (presented in the form of small videogames). Figure 1 represents the steps in the process: 1) educational goals definition, 2) game design and implementation, 3) interaction analysis and 4) results visualization. In the next subsections, we detailed each of these steps.

### A. *Educational goals definition*

Educational goals are the core and basis for the process. Teachers have to define what the students should learn in the exercise, and which concrete skills they want to test. Clear, concrete and precise goals will help in the subsequent steps.

The definition should follow a top-down approach, starting with a general goal (e.g. teach basics of structured programming) and then break it down into sub-goals (e.g. teach *for* loops, teach *while* loops, teach functions…). Teachers must narrow the goals domain, discard those too ambitious and keep them as simple and concrete as possible.

Each educational goal must have a binary result, (i.e. a student achieved the goal or not). Some goals can rely on a scale (e.g. student accomplished 40% percent of this goal), to give a more fine-grained result, but these results also should give a binary output (e.g. if a student accomplishes more than 60% of the goal then achieves the goal), to simplify later visualizations.

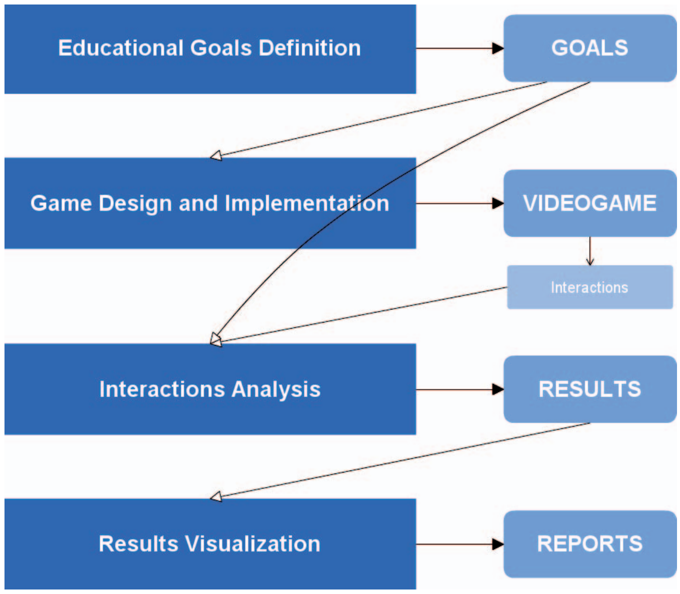


Fig. 1. Our approach follows four steps: 1. Definition of the educational goals for the exercise/videogame 2. Design and implementation of the game. 3. Interactions analysis to establish relations between educational goals and interactions 4. Visualization of the results.

Ideally, the game designer supports and gives guidance in the decisions of this step. The designer has more insight on which goals and ideas can be translated into the game and also keeps in mind requirements and constraints conditioned by the following steps of the process, like which game mechanics will be proper for the goals (if any) and which interactions will be necessary to capture to assess them.

### B. *Game design and implementation*

In this phase, the game designer (or the game designers/programmers) takes control. His job consists in designing and implementing a game that covers all the educational goals defined in the previous step.

The design process will define the theme, the scope and the mechanics of the game. Settings like the target audience or the content subject will affect the theme. Variables like desirable time to complete the game, level of difficulty, in addition to the educational goals themselves, will define the scope. And finally, content of the goals will define for the most part the game mechanics.

Teachers will assist in the process, validating the educational and pedagogic approaches implemented by the game.

### C. *Translating game interactions into goals achievements*

Although we treat it in a separate step, translating game interactions (the "observable factors" in [4]) into goal achievements is intimately bound up with the game design phase.

We face two aspects to connect interactions with educational goals: 1) game designer/programmer decides how the data are transmitted to the teacher (i.e. the communication-back process); and 2) teacher and designer have to define which concrete interactions *prove* that a student accomplished a goal (i.e. the analysis process).

Relation between interactions and goals can be as complex as desired. In many cases, however, it is feasible to establish direct relations between a concrete interaction and an educational goal. For example, if the game presents a puzzle that requires knowledge about two electronic components, solving it implies that the student knows those components (i.e. if the student solves the puzzle then the student achieves the goal), and we put aside complex data analysis to extract this result.

For goals that use a scale, it will be necessary to extract certain values to calculate its result. For example, in a quiz game, one goal could be the result of dividing the number of questions correctly answered between the number of questions asked.

Analysis of the results can take place in two modes:

- *In-game assessment*: the game assesses all the goals internally, and the teacher receives only the final results. In this way, the teacher does not receive the interactions performed to achieve the goal. This mode can be appropriate for games in which relation between interactions and goals is very simple.
- *External analysis*: the game sends all the interactions to an external system, which collects, analyzes the data and finally shows the results to the teacher. This mode is more appropriate if relation between interactions and goals is more complex (e.g. several different interactions can lead to the same goal) so teachers can have more detailed information about the path followed by students for each goal completion.

### D. Visualization

All the efforts from previous steps focus on giving to teachers a set of useful reports with feedback and information about students' performance.

Following the idea of goal oriented visualizations [9], reports for our approach primarily show goals achieved by each student in the concrete exercise/videogame. Combinations of students and goals can spot goals with best and worst success rates, and best and worst performers.

In addition, as secondary reports, student can also have access to some of the results from the data analysis, with auto-evaluation purposes (e.g. knowing which goals they accomplished and the knowledge associated with them).

### E. Deployment in the classroom

Finally, teachers must decide the deployment of the videogame in the classroom: where students resolve the exercise (during laboratory practices or at home), if it is mandatory or optional, if the results have any impact on the students assessments, if there is a follow up session or other content related, etc.

## IV. Study Case

We tested our approach in a Computer Science Degree classroom, with students and content from a Web Technologies class in the Complutense University of Madrid.

In the usual mechanic for the class, the teacher first presents the lesson content through theory (with a slides presentation) and then proposes some related exercises to the students. Sometimes, they must develop a lab practice during several weeks, and others, they resolve basic exercises during classroom time, while the teacher clarifies doubts.

For this study case, we took one of the items of the course content –the XML markup language– and substituted its exercises for a puzzle videogame.

We now break all the steps taken, following the process described in section III:

### A. Educational goals definition

We took as educational goals the same ones the teacher had defined for the substituted exercises, which were:

- *Create simple XML documents*: the student can create a document with a root and a few children nodes.
- *Create XML documents with attributes*: the student can use attributes in some of the nodes.
- *Create new documents interpreting a DTD*: the student can create documents based on a given DTD.
- *Create complex XML documents*: the student can create documents with several nested children and attributes.

### B. Game design and implementation

The main educational goal for the exercises was to teach students to write XML documents. So we decided, inspired by some tools aimed to teach programming languages like Scratch [10], that students should introduce XML documents to control the game.

We choose puzzle game with several phases. In each phase, students must lead a spaceship to a wormhole (the exit), introducing XML documents (see figure 2). The XML documents represent actions that the spaceship can perform: move, rotate, shoot and disappear, each with several variants regulated by attributes.

### C. Translating game interactions into goal achievements

The game mainly broadcasted two types of interactions: phase completions and XML documents introduced in the text area. Next, we detailed how these interactions were linked to the each educational goal:

- *Create a simple XML document*: this was the simplest goal, and it was achieved the first time a student sent a valid XML with a root and a child.
- *Create XML documents with attributes:* it was achieved after the student sent 5 valid XML documents with 5 different attributes.

- *Create new documents interpreting a DTD:* while players move through phases, they find spaceship parts that give them new abilities (rotate, shoot…). This new abilities are expressed through a DTD that is expanded every time a new part is found. In each phase the student find a new part, is mandatory to use the new ability, i.e. the student must interpret the updated DTD to finish the phase. This goal is achieved once the player passes the last phase in which a spaceship part is found.
- *Create complex XML documents:* players can complete many phases using several tiny XML documents, but they can also accomplish these phases grouping those tiny documents into a complex one (and obtaining a better score). However, there are two phases that require the use of a complex document to pass through, so this goal is achieved once the player beats these two phases.

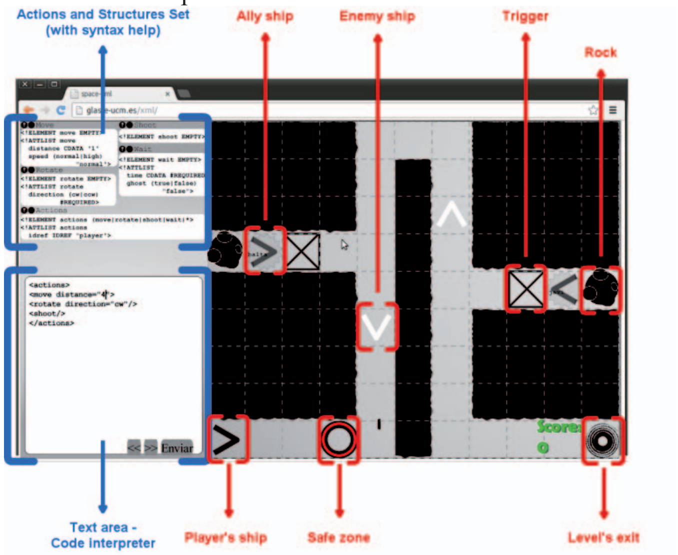


Fig. 2. Lost in Space <XML> screen capture. The goal in each phase is to lead the player's ship to the exit, introducing XML documents as orders in the text area.

As an extra (and although it has no real effect over the educational goals) the game also sent the score of each player in each of the phases.

*D. Visualization*

Figure 3 and figure 4 shows the teacher visualizations for the *Lost in Space <XML>* game. Figure 3 shows the results of each student individually. One row contains the data for one player in five columns: the session id, the name, the current phase, the score and the educational goals completed (in the form of badges).

Figure 4 box shows all XML documents sent by the students. This report can filter the results by student, and by valid or invalid documents. With this view, teacher could easily find those most common mistakes committed by the students, and intervene to fix them.

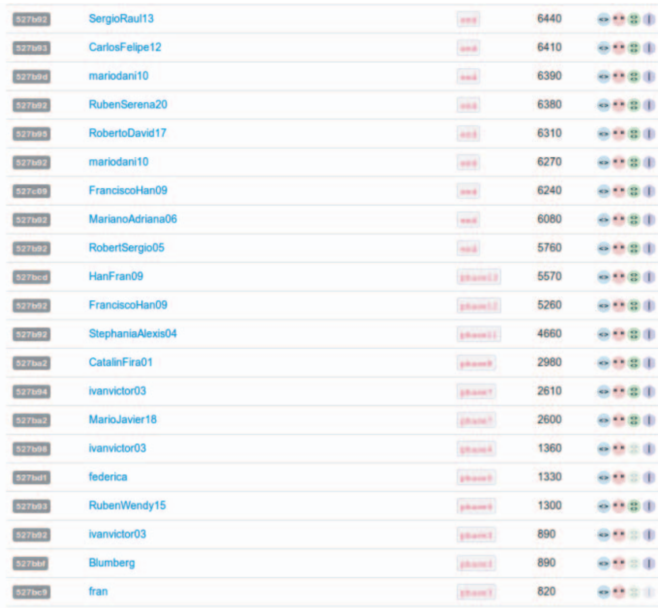


Fig. 3. Teacher visualization of students results. This visualization has 5 columns: a session identifier, user name, current phase, current score and educational goals achieved (in the form of badges that are "turned on" when they are achieved).

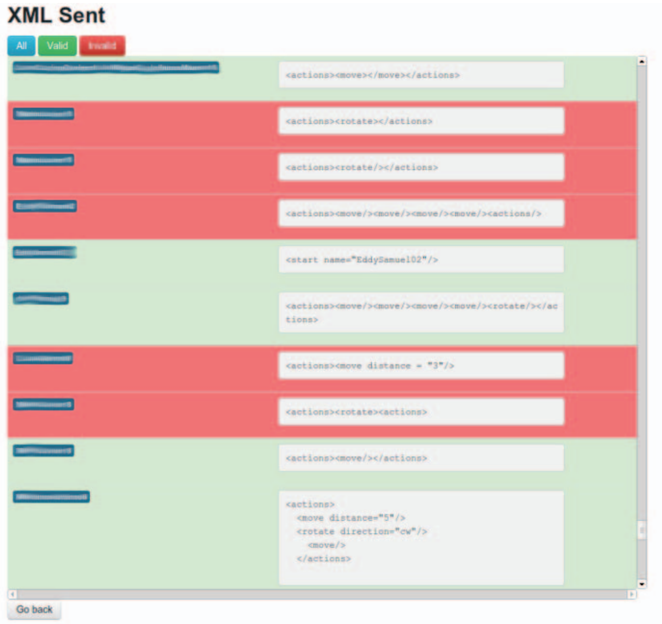


Fig. 4. Teacher visualization of XML sent by the students. This visualization contains 2 columns, one of the username and other with the XML document sent. Teacher can filter valid and invalid documents, and also filter the documents by user name.

Also, for this game, we developed a view for the students that showed them their individual results (figure 5). This view was mainly showed to students to encourage them to try again.

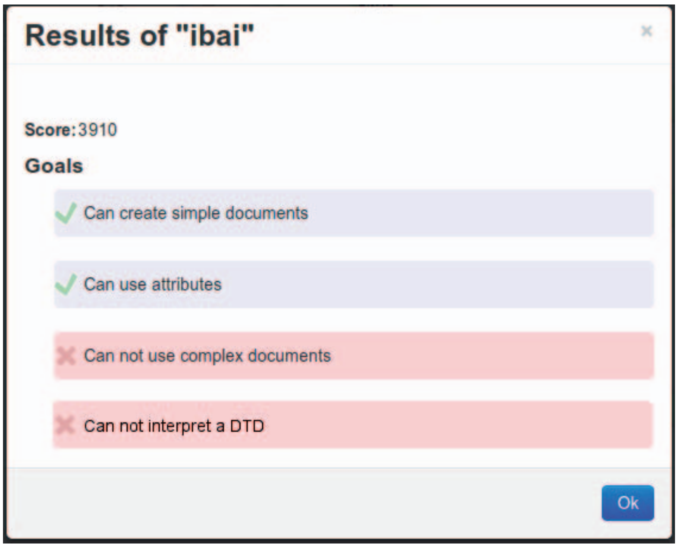


Fig. 5. Students visualization. In this report, they see their score and the educational goals achieved.

### *E. Deployment in the classroom*

34 students played the game in a laboratory session (figure 6), two days after receiving a class about XML fundamentals. For the first half of the class, students were unaware that we were tracking their results, but we showed them the ranking half way the class was through.

During the class, students enjoyed the game and remain active the whole class, exchanging comments and scores with their partners.

Fig. 6. Session with the students playing the game. Due to space restrictions, in this session students played by pairs.

## V. Conclusions

In this paper, we present our approach to simplify teachers' task when using games by providing real-time information of the actual students' use of the games while in the classroom. This approach is specially focused on delivering assessment data to the teachers.

We emphasize three main aspects: define precisely the educational goal of the exercises, establish a reliable connection between game interactions and educational goals, and design clear visualizations that provide useful information for the teachers about the actual use of the games.

We tested this approach in a real case, and we obtain as results a game to teach XML basics and a tool for teachers to visualize the students' interactions and goals achievement.

Based on the experience with the study case, our approach fulfilled our needs. The goals for the *Lost in Space <XML>* game were simple but adequate four our needs, and the analysis requires simple techniques, which leads us to think that for small exercises, it is not really necessary a complex data analysis.

Also, the goal oriented visualizations served the teacher to have a more complete view of the students' performance.

However, this study case was isolated, and some challenges remain opened, like how we can integrate results from several exercises/videogames and the long term effect on teachers' perception.

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