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Game Learning Analytics, Facilitating the Use of Serious Games in the Class

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***Title*— Game Learning Analytics, Facilitating the Use of Serious Games in the Class**

***Abstract*—Serious games are still complex to deploy in classrooms for average teachers. Game Learning Analytics can help teachers to apply serious games, using data from students' in-game interactions to provide learning information. Many teachers do not see games as tools to improve their classes, particularly due to perceived loss of control when using games; so it is essential to retain their benefits while avoiding most of the deployment complexity. In this paper, we describe our experience using Game Learning Analytics to encourage the application and deployment of Serious Games in class as learning tools.**

***Index Terms*— serious games, learning analytics, game-based learning, educational data mining, stealth assessment**

I. Introduction

This work is an extension of the paper published inside the EDUCON 2019 conference [1]. In this extension, we have included a new section regarding real-world use-cases of serious games, which have put into practice the steps and recommendations described in the paper to encourage the application and simplify the deployment of Serious Games in the classroom. We have also pointed out guidelines on the use of Game Learning Analytics, and the application of serious games as homework.

The immersive and engaging nature of games has proven to be a promising and effective environment for learning [2]. These characteristics have increased the interest regarding serious games, that is, games for which the main purpose is not that of entertainment [3]. While this main purpose is frequently that of learning, it is also possible to find serious games that strive to raise awareness, or to change an attitude or behavior [4]. Serious games have been developed for use in many different areas (e.g. education, military), where they have proven to be an effective learning material [5]; however few of them have gone through a formal validation process to prove that they meet their intended goals (e.g. teach some topic, improve some skill) [6]. Moreover, most serious games were developed in controlled environments, where teachers do not have an active role, and are difficult to scale up and deploy in real scenarios by non-specialist staff. A common scenario of application of serious games is in education, where games are used as an additional resource for educators who provide the game to students for those students to play in class.

However, when it comes to actually applying serious games in educational settings, educators may face several issues (not only technological ones) which make their work more difficult:

- Specific technology or platform requirements: some games require a specific platform such as Android or MS Windows; and/or specific hardware components such as special controllers. Not all schools are able to fulfill the specific technological requirements to apply the game successfully.
- Average gameplay duration: it is important to note whether the game is designed to be used in a short session of one or two hours or whether it is intended to be played for several sessions throughout the course. If the intended duration is so long that it may not fit into a single class session, the design of the game will have to include dynamics to facilitate continuation of gameplay between different sessions.
- Adaptation for users with disabilities or special needs: for instance, if the game is geolocalized and the educator has students with motor disabilities, educators may have to adapt the game; or may even not be able to apply the game at all.
- Number of devices: the number of devices where students play can be limited, and the game may not be effective when played by groups of players.
- Lack of skills with videogames: educators may be overcome by their students in the use of technologies in general and videogames in particular, thus feeling incapable of staying in control of the class.

Even when a game meets all the requirements for its application in the classroom, educators may not find its application that obvious. As educators, they may not be familiar with the technology used in the game and may not feel confident with the actual games' deployment.

Training for teachers may also be required so they are provided with tools to help them when applying the game, and guidelines on what educators and students need to do

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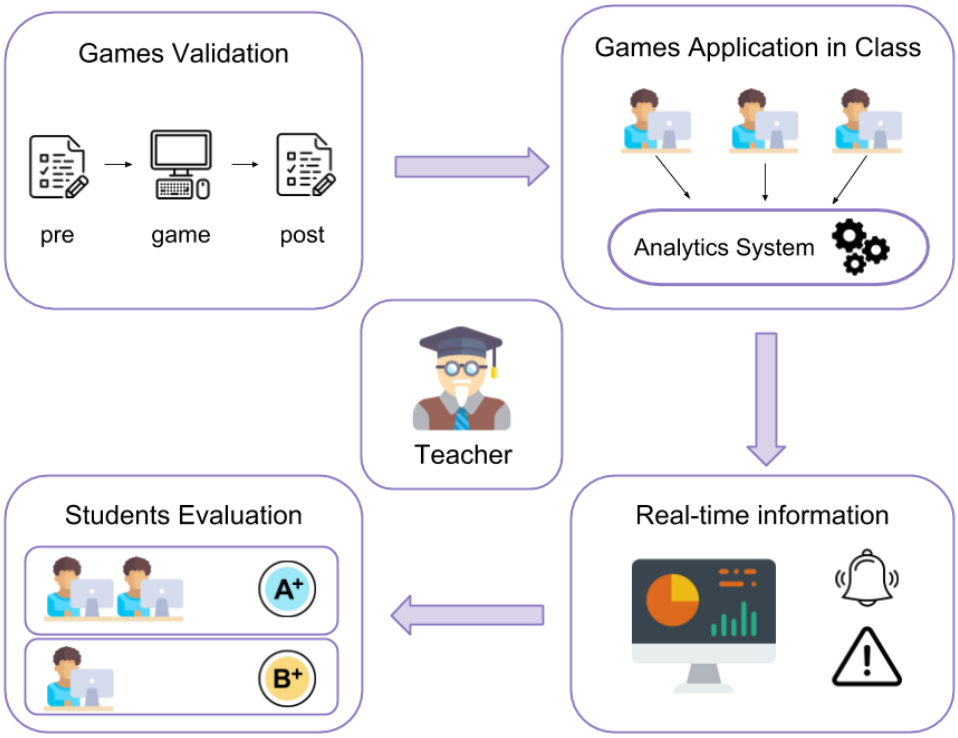

Fig. 1. Teachers' interaction with serious games. Starting from the top-left corner, and following the arrows: game validation, classroom use, real-time monitoring via dashboards (available both during and after game-play), and student evaluation / feedback.

while the game is in play. Moreover, it can be difficult for educators to actually know what their students are doing while playing, whether they are actually learning or not, or how to adequately apply games in classes for they to be more effective.

To avoid these issues, it is key that developers and researchers keep in mind educators' needs at the design and development stages and try to make games more "human". In this sense, educators should not need to be experts in games or in technology for effectively using them; educators should be aware of what students are doing in the game at any moment and capable of quickly looking up information on whether they are learning or not; and the game should meet its intended teaching goals, so educators can be sure that letting students play in class is an adequate learning activity. All these conditions are necessary to facilitate the adoption of games by teachers.

Although the use of games in schools has proven to greatly benefit students, this does not mean that they are the only stakeholder to be taken into account. To promote the current use of games in education and to be more effective, we consider a holistic approach, where educators are also an essential part for those educational games that are going to be used in class, since teachers are in charge of their classrooms and they are the key stakeholders that decide whether or not to apply games in them. Whether educators fully understand and know how to effectively apply games or not can greatly affect or even completely determine the actual application of games with students. Therefore, we consider that educators should play a key and active role in the full lifecycle of those serious games: inception and design, initial game validation, applying games in classes obtaining information at real-time about their progress and results, and automatically evaluating students based on their in-game actions. The role of teachers needs to be pedagogically active at all stages: planning the session, during the gameplays and after the sessions [7].

To provide information that helps educators, interaction data can be collected from students' gameplays to provide a great insight into students' actions in the game. Learning Analytics data from games (i.e. Game Learning Analytics data) can be collected and analyzed to evaluate, validate and improve the games, but also to help educators avoid some of the previously mentioned issues.

The field of Game Learning Analytics (GLA) builds upon two separate fields: Game Analytics and Learning Analytics. The former deals with the in-game tracking of interactions from players on games in general, usually with the goal of increasing players' engagement and the acceptance of games [8]. Meanwhile, the later focuses on understanding player/learner processes when interacting with different learning systems (e.g. MOOCs, LMS) [9]. The main focus of the studies using GLA is on assessment, targeting different stakeholders, although several different purposes for its application exist, including students profiling [10].

The application of GLA should not reduce the role of educators, but instead change it as the learning activity also changes [11]. Technology should simplify and not obstruct their work during the whole process: from the initial validation of games, to the application of games in classrooms while data is being collected in an Analytics System, to obtaining real-time information that reveals what students are doing while they play, to, finally, being able to evaluate students based on their in-game actions.

Fig. 1 summarizes this process where educators or teachers are placed in the center. Notice that the educator should also

be involved in all stages of the design and development of a serious game.

In the following sections, we go through all the steps of the lifecycle of serious games designed to be used in class, focusing on the tasks of educators and on how game learning analytics data can simplify their use of this technology in classrooms. The rest of this paper is structured as follows: Section 2 describes some of the considerations and steps to formally validate serious games. Section 3 focuses on the application of games in actual classrooms, including what educators need to do before to prepare the activity, what information they can obtain while games are in play, and what they need to do after the gameplays are over. Section 4 proposes an additional use in which learning analytics data can be used to help educators evaluate students based on their in-game interactions. Section 5 reviews three scenarios where we have used serious games for the uses previously described on Sections 2, 3 and 4. Finally, Section 6 summarizes the main conclusions of our work and points out some limitations.

II. Formal Validation of Serious Games

To ensure that games meet their intended goals, the first step is to perform a formal validation. The most widely accepted and commonly used method to validate serious games is to conduct a pre-post experiment consisting of three phases: first, students complete a questionnaire before playing (pre-test), then students play the game from beginning to end, and finally, after finishing the gameplay, they complete a final questionnaire (post-test) [12]. Both pre-test and post-test usually have the same (sub)set of questions. The goal is that this questionnaire assesses players' characteristics before and after playing about the topics covered in the game (the specific characteristic depends of the serious game purpose including, for instance, knowledge, attitude or awareness). Results of both tests are then compared to see if the increase in the specific player's characteristics is statistically significant. If that is the case, as between both measures the only intervention is the game, it can be concluded that the increase in that characteristic is due to the game's effect, and therefore the game is considered formally validated. There are plenty of examples in literature that use this approach to validate serious games including, for instance: a game for children with autism to learn emotions [13], a game for patients to manage pain after surgery [14] or a game to raise awareness about bullying and cyberbullying [15].

It is also important to consider the way the game is going to be played, and on which platforms; both when designing and when validating the game. Not all schools have access to the same devices or the same quantity, and there will be cases in which the educator will need games for mobile devices, while in other cases they will prefer to use desktop computers.

In the validation stage, if we consider the case of a learning game designed to be used in class, the questionnaires provide a measure of how much students know about the topic before and after playing the game. In order to meet the equity and improve the validation process, researchers should provide the results to the teachers and how to assess the effectiveness of the game. The pre-test can provide educators a measure of how much students know about the topic before playing the game, or even it can be used as an assessment questionnaire to measure their knowledge of the topic. After playing, the post-test can show educators the effect of the game's application and how much students know after playing – and, if the game is effective, also how much students have learned by playing. The validation itself can easily be carried out during a class session where educators request that students fill in the pre- and post-tests before and after playing the game.

If possible, the validation of the game should be done on all possible platforms with which it is compatible. For example, it is not the same to play on a tablet than on a computer; and this difference can have an effect on the learning and experience of the final player [16].

The validation process described, however, assumes that an accepted questionnaire that measures the specific characteristic (e.g. knowledge) covered in the game exists. But this assumption may easily not be satisfied, as few validated questionnaires already exist or have been constructed for serious games [17]. If there is no accepted questionnaire to validate the game, the complexity of the process escalates as the validation questionnaire itself must first be developed and validated. Once the game has been formally validated, it can actually be applied in larger classes as it is already proved that it is effective.

On this validation process, GLA can provide a further insight about players' progress and results. Collecting data from users' in-game interactions can help to improve and validate the game design; for instance, to find bugs in the game, highlight features to improve, or check if the game time and interactions are in line with the developers' expectations. For this purpose, the Simva tool [18], [19], created to simplify these validation experiments with serious games, can be of great help. Among its features, Simva manages questionnaires creation and assignation to classes of students, students' creation and anonymization, and collection and storage of both questionnaires and in-game interaction data.

III. Application of Games in Classrooms

After the formal validation stage, the serious game can be applied in real scenarios. For example, the game may be used for homework, or as an optional activity to be carried out at home. Another possibility is to use the validated games as a learning tool in a class session with at least one educator supervising the activity. If the game is played with internet connection and sending data to the analytics system, educators could receive information both during and after gameplays have been completed. This information may include whether students have learned or not, if they have encountered issues playing or even student assessments based on their in-game actions.

As a homework activity, the game can use GLA to provide teachers with progress reports, allowing teachers to know which students have played and/or completed the game. In this scenario, relevant GLA information may include the most common problems or phases in which students became stuck, the total time they have played, or the score or degree of learning they have achieved. The application of GLA in these cases allows the teacher to monitor the progress of their students at all times, if they can connect to the Internet.

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When applying games in classes, it is essential that educators fully understand the content and the mechanics of the game that they are applying. As a starting point, it would be ideal for educators to have played the game before applying it with their students. Some educators may not consider it that useful, as they are commonly not part of the intended target group of the game; however, actually playing the game can provide educators with a great deal of information about what their students will face when they are the ones playing. Although we consider that playing the game is essential, by itself it may still not provide educators with full information about the purpose of each part of the game, or the design decisions, among other important details. To complement the experience of playing the game as their students will do, a game manual for educators is extremely convenient: not only can it provide additional information on the game to simplify its application in class, it can also explain the rationale behind the game design and mechanics. The manual for educators could include, among others: downloading (if needed) and installation instructions for the game; requirements for its application; goals that the game aims to achieve; details about the game content (e.g. levels or days in-game, quests or tasks to complete, mini-games included, characters that appear, and even solutions or hints to solve the game's challenges); purpose of each part of the game; additional information about the context of the topic the game is about (this can be used to raise a discussion with students after playing or to provide further information to complement and complete the content of the game); instructions for students; a list of frequently asked questions when applying the game, and so on. Some examples from literature where a manual has been provided to educators when applying games in class to support their tasks include [20] or [21].

Once educators are familiar with the game content and mechanics, a first step towards simplifying the task of applying games has been achieved. Building up from this knowledge, it will now be much easier for educators to apply the game in their classes, helping students that need it and being aware of what students are actually facing in the game. But an additional step is required for educators to maintain control of what is happening in their classes when applying games. As students typically play individually, each student goes through different situations at each point of time, so it would be difficult for educators to be able to even know what each student is doing at a given moment. This can greatly undermine educators' trust in applying games in classes as they may feel that they do not longer control what students are doing. To avoid this perception, it is essential that educators obtain a complete-enough range of information while students are playing.

When collecting interaction data, fairness also needs to be ensured. If developers or researchers are collecting data to improve the game design or deployment, all other main stakeholders involved in the process, including educators and students, should obtain a clear benefit from the use of this technology. Therefore, analytics should provide students with a better and more authentic learning experience, while teachers should keep control of their students' progress, with access to real-time information about how they are playing the game and even data that can contribute to the final student evaluation. For students, fairness can also be ensured if educational opportunities are provided according to students' level of need and ability [22]

A. Real-time information for educators

A further step to simplify educators' task when applying games in schools is to ensure that they do not lose control of their students' progress while they are playing. An easy way to give educators information about what students are doing in their gameplays is with some type of visual analytics that aggregates all the game learning analytics data coming from each student's gameplay interactions. This visual information

Fig. 2. Sample dashboard to show information for teachers while games are in play.

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can be shaped as a dashboard, where multiple visualizations are combined to provide an overview of the classroom. It may also be helpful if this dashboard can be filtered by student so educators can also see the information about specific students or obtain more in-depth information about individuals, if needed. The dashboard should collect data from students' interactions with the game and show the information derived from that data at near real-time so educators can monitor the current situation of their students. The information shown may include: in which part of the game students are at each moment, chosen paths, progress, actions in the game, responses, scores, times, or completion, among others. For instance, Fig. 2 shows an example dashboard for teachers including (from left to right, top to bottom): total number of active players, to verify that all students are playing; percentage of players that have reached each game ending, to know if all have reached the most desirable ending or not, which may depend on their in-game actions; number of players who have gone through each game-day, to know the general progress of the class in terms of game levels or days completed; number of scenes completed for each player, to know the specific progress of each student; and the value of one in-game metric (in this case, level of friendship with an in-game character) for each student, which may provide deeper insight into in-game actions taken.

An additional visual element that may help educators while games are in play is the use of alert and warning messages [23]. These messages can be configured prior to the application of games (or be pre-configured by the game development team) to define the conditions under which each specific alert or warning will be triggered. When these conditions are met, the alert or warning message will be shown to the educator, together with the identifier of the student whose gameplay data has satisfied those conditions. With these defined messages, educators can be notified at near real-time when specific situations that may require their immediate attention occur. This system can be used by educators to allow them to help students that encounter issues in their gameplays and cannot move forward, and to provide additional tasks to students that advance too fast and may finish the game earlier than expected. This method also improves fairness as all students, regardless of their speed or ability to complete the game, can take advantage of the activity without wasting time stuck in the game or finishing it too early.

The previous process has a fundamental requirement: interactions carried out by students in the game need to be collected following some standard data format that can be used to define and populate the visualizations. In our proposal, we use the Experience API for Serious Games (xAPI-SG) profile [24] that standardizes the data collection for interactions performed in serious games. Following the definitions of this profile, it is recommended to provide a set of default teacher visualizations that covers the most common scenarios without any required additional information or configuration from teachers [25].

B. Post-game activities

When applying games in classes, we also strongly recommend educators to ensure that, after students finish playing, there is time for a post-intervention activity. Each game should have such an activity associated with it, and prepared in advance by educators, depending on the goal of the game. In this sense, it is important that games provide the necessary tools so that educators can take advantage of them and relate them to the curricular content of the game:

- The post-game activity may be a simple discussion or debriefing about the common experience they have just gone through, so that the game is the tool that triggers the discussion. This class discussion after playing games is key to promote reflection [26] in an open climate where students can share their experiences and feelings playing the game.
- Educators can use this time after the activity to help students link the game content to that of the real world and include additional information that complements the gameplay. For instance, if the purpose of the game is increase knowledge, educators may provide additional information required in the curricula and not covered in the game or review the key take-home pieces of information. In the case of games to change

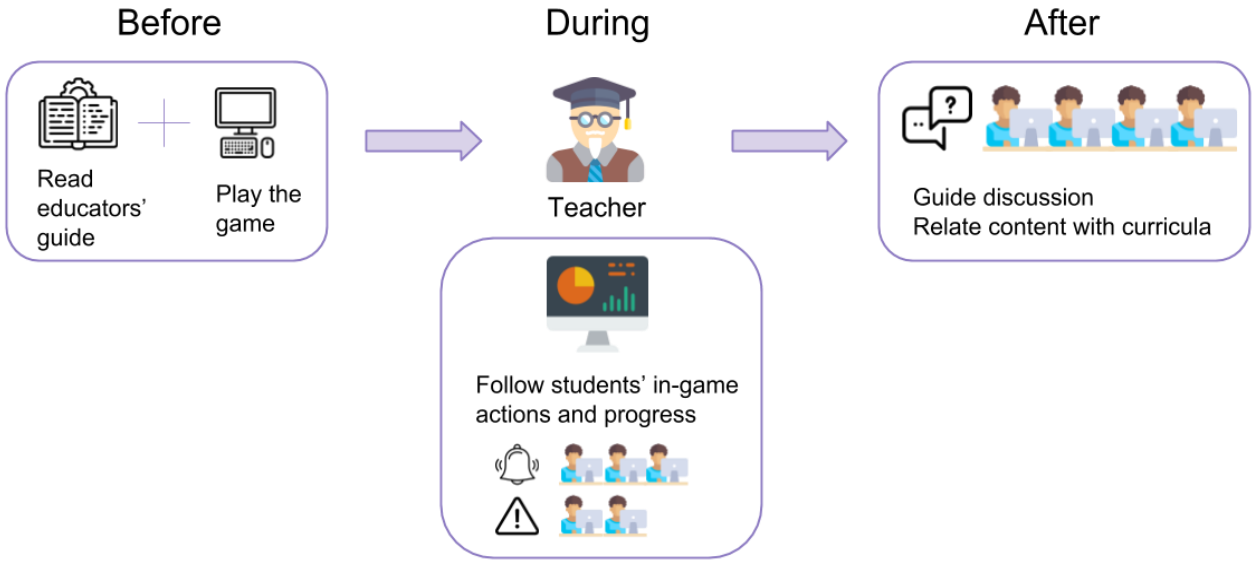

Fig. 3. Teachers' activities before, during and after using games in classes.

attitude or increase awareness, the postgame discussion can be used to go through the topics covered in the game, extract conclusions and compare the situations depicted in the game to those students are familiar with.

- A final option is to provide players with exercises where they can apply the content they have learned with the game. These exercises may be written (e.g. tests, or even homework) or oral (e.g. role playing), and may even be used for assessment purposes.

As mentioned before, some ideas for this post-game activity may also be included in the educators' manual. For instance, in [27] teachers reviewed the key concepts of the game after the activity to ground learning and connect the game content with the curricula.

Fig. 3 summarizes educators' activities before, during and after the application of game in classes. Before, reading the educators' guide and playing the game; during the application, following students' in-game actions and progress with visual information, alerts and warnings; after gameplays, guiding the discussion and helping students relate the content of the game with the curricula.

IV. Students Evaluation Based on In-game Interactions

A final step to simplify educators' tasks when applying games in education is that they should be able to formally and automatically evaluate their students based on their actions while playing the game. A commonly used method to evaluate students follows the structure of the one used when validating the game itself: players' knowledge is measured before and after playing, with pre- and post-questionnaires; and the difference between their results in each test shows how much students have learned while playing. If the result obtained in the post-test is better than the one obtained in the pre-test, we can infer that students have learned something while playing the game. Although this is an effective method to evaluate learning, we consider that it is not that efficient. Players have to complete the same questionnaire two times (as the pre-test and post-test contains the same set of questions to be able to compare them) - in addition to playing the game, which most students would really prefer over filling in questionnaires. This method also restricts the time left to play the game, and also the time left after students have finished playing for educators to either discuss the game content or to provide additional information about the topic if needed. Also, the questionnaires themselves need to be prepared in advance, which takes time and effort, and educators need to go through all the results in both pre-tests and post-tests to actually assess students.

For all these reasons, we consider that this pre-post method can be improved by taking advantage of the power of learning analytics data collected from in-game interactions. Following some of the aspects of the work done on stealth assessment [28], our proposal is to predict students' knowledge after playing (as usually measured by the post-test) based on the actions that players carry out in the game. To do this, the first step is to create the prediction models that take as input the interaction data and output as a result a prediction of student knowledge. The game validation step provides a great opportunity to create models that can accurately predict post-test results based on data from player interactions in the game. In this step, we actually have the results from the questionnaires, so we can train the algorithms and evaluate their performance against the actual data (for instance, applying cross validation, all data collected can be used both to train and test the prediction models).

Once we have developed accurate-enough models and selected the most promising one, we can use it as the assessment method for students who play the already-validated game. In this case, the model created will again take as input the information from students' interactions in the game and predict students' knowledge after playing the game based on these interactions. This method avoids the need to further carry out the post-test: students complete the pre-test (if needed), then play the game and, after their gameplays are finished, they will automatically be given a score that represents their predicted knowledge after playing. The score thus obtained will be the result of the prediction model applied to the input data received from the student's gameplay. It may also be necessary to include the pre-test as input for the prediction model, which allows us to measure how much knowledge is gained based on the existing knowledge of students, as reported by the pre-test. Ideally, we would like to avoid the pre-test as well, so prediction models could predict the post-test score only based on interaction data. In this case, the time to play the game and the time left for the educator could be even further extended as neither the pre-test nor the post-test will need to be carried out.

As in the case of obtaining real-time information while games are applied in classes, the described approach with prediction models is based on the key fact that all collected data from students' interactions must follow a standard data format. This standard data format is used as the format for the inputs received in the prediction models. Again, in our proposal, we use the accepted and standardized xAPI-SG profile to capture interactions from the serious games. As long as game interactions captured follow this standard, we consider that our approach could be more generalizable than the approach of stealth assessments, as once the prediction models are created at the validation stage, no further game-specific features are required to be able to evaluate students.

V. Real Cases

As seen on the previous sections, educators play a key role that affects the design, development and deployment of serious games. Their role is especially relevant for those serious games focused on their use in class, as educators are the ones who are going to decide whether or not to use them as a learning tool for their students. On this section, we describe three experiences in which we have put into practice the different points that we have exposed previously in real scenarios with two different serious games. The first serious game used is *Conectado*, a graphic adventure that puts the player in the shoes of a cyberbullying victim and whose objective is to make young people aware of bullying as well as to create empathy towards the victims. The second serious game used is the First Aid Game, a simulation with narrative structure that aims to teach players first aid techniques for three different emergency situations.

A. *Formal validation of a serious game*

Conectado is a serious game designed to be applied by teachers in their classrooms. It is important to validate that it fulfills its objective, which is to create awareness about bullying, but also to validate its applicability in a classroom and gather the opinion of teachers. It was validated in a set of real-world experiments. This also proved its effectiveness in classrooms of different sizes and with very different equipment.

The first step towards the game validation was to evaluate the effectiveness and usefulness of the videogame for its target players. For this purpose, validation experiments were carried out with 257 students between 12 and 17 years old. The second step was to validate its applicability in class and gather the opinions and feedback of teachers regarding the game. For this validation, 93 teachers and 113 students of educational sciences degrees participated in experiments to test and give feedback about the game. The full details of these two validation steps and their respective experiments can be found in [15] and [29].

In the above experiments, GLA was used to measure the time it took the players to complete the game, since one of the requirements was that a full gameplay should not last longer than a standard 50-minute session slot. Data was also collected from all interactions to assess whether players got stuck in a particular scene or spent a lot of time not interacting with the game, which could indicate low engagement. And finally, through GLA, the choices made by the players in each of the dialogues and the end of the game were collected in order to evaluate if the level of awareness before and after playing was related to these interactions, although no clear relationship has been yet been found.

In addition to the GLA data collected, an initial and a final questionnaire was used to assess the players' awareness of bullying before and after the gameplay, as well as their opinion about the experience.

B. *Application of a serious game in class*

Conectado is an open-source, free serious game designed to be used a tool in class for a teacher or a group of teachers. The game not only aims to raise awareness about bullying, but also to spark debate about the experiences of its players. This reflection debate should be guided by the teacher, and it is important that the teacher sees the videogame as a tool that can be adapted in different ways in the class dynamics. To do this, a teacher's guide was created that explains each feature of the game and how to take advantage of it.

The guide provides teachers full details about each of the phases of the game and the events that occur on each phase. For each of these events, the guide explains the issues related to the bullying it deals with and how they can be used to spark self-reflection in players after the game session. Additionally, the guide contains a section summarizing the terminology about bullying and serious games; a section of frequently asked questions to solve common issues that teachers encountered when using Conectado; and another section covering the installation of the game.

It should be mentioned that both the game and the guide have been used by a guidance counselor in a school where we were able to attend as observers, watching the different sessions while they were taking place. In this way, we could verify that the teachers of the school were able to deploy and use the game satisfactorily as a tool, fully adopting it as their own. Moreover, the counsellor was also able to use and apply these resources to carry out a reflection session in which she combined activities proposed by the guide with other activities and different resources.

In this scenario, the role of GLA was secondary, being mainly used to check that all the students were playing and interacting with the game.

C. *Students' assessment with a serious game*

The *First Aid Game* is a game-like simulation that aims to teach first aid maneuvers to players between the ages of 12 and 16, in three situations: chest pain, choking and unconsciousness. The game presents each situation as a different level players needs to successfully complete. On each level, players encounter different situations in which they have to choose among different courses of action, presented visually or as multiple-choice questions. An in-game phone is also available to call simulated emergency services.

The game was previously fully validated with pre-post experiments using a control group that had attended a theoretical and practical demonstration by an instructor. This validation experiment, fully detailed in [30], proved that the game was indeed effective and that players increased their first aid knowledge as a result of the gameplay. More recently, we conducted a new set of experiments [31], [32] collecting both pre-post questionnaire data and GLA interaction data from 227 students between 12 and 16 years old.

With the captured interaction data, we created different prediction models to predict the post-test score of players (that is, their knowledge after playing). To predict pass-fail categories we trained models using logistic regression, decision trees and Naïve Bayes, while to predict exact post-test scores we trained models using linear regression, regression trees and support vector regression. The resulting models showed a high prediction accuracy, with over 98% recall and 89% precision for the best models obtained to predict pass-fail, and 1.4 mean error (out of 15) for the best models to predict score. Prediction models showed a similar accuracy when excluding the pre-test from the input.

The role of GLA was therefore essential towards the assessment of students, as the most relevant variables on the predictions models obtained were related to GLA information. In particular, some of the variables with higher prediction power were related to the score obtained on some in-game levels or the number of interactions with the main game character.

VI. Conclusions

There is still much to do to enhance and extend the presence of games in education. Educators are key to promote the application of games in actual educational settings. However, educators cannot be expected to be experts in the use of technology. Therefore, to simplify educators' application and deployment of games, games must provide a clear benefit in terms of their usefulness and contribution; and also provide the necessary tools to simplify educators' task.

First of all, games need to be formally validated with an

accepted method, such as pre-post experiments. After a candidate game has been formally validated, educators need to fully understand the games' content and mechanics to be able to effectively use it in their classes. For this purpose, the experience of playing the game themselves as well as reading a game manual or teachers' guide can be of great help.

When students are immersed in the activity and their gameplays, visual information dashboards can help educators to keep control of their progress and actions effortlessly and unobtrusively. Alerts or warnings can also be used to make educators aware of specific situations that may require their intervention. Finally, game learning analytics data may be a more direct form of assessment, which is not based on an external measurement but instead on actual in-game actions. Prediction models developed at the game validation stage can automatically provide an evaluation of students' knowledge after playing the game, based on their interaction data.

The three experiences described have showcased different applications of games in real-world settings. The formal validation and real application in classes of a serious game (Conectado) has showed how pre-post experiments can be complemented with GLA data to provide richer information and enhance the game; while the use of an educational guide to support teachers has proven to be essential for teachers to fully understand and become comfortable with a learning tool that they are going to use with their students. The assessment of students via prediction of learning showcased on our third experience (First Aid Game) provides an approach to assess students based on their in-game interactions, moving from the classical pre-post questionnaires to richer information as provided on the GLA interaction data.

However, this application model for serious games is still error prone and presents certain limitations and requirements that need to be considered. First of all, technology issues may appear before or during deployment in schools. If the collection of GLA data depends on sending it to an externally-located analytics system, it then relies on the schools' internet connection which may also fail. The analytics system also needs to be reliable and be ready to handle the collected data, both in size and format. These and other technological issues imply that the application of games in schools will always be at risk of requiring technical support, which can restrict their application by educators on their own. Another issue to be taken into account when collecting data is privacy and security, especially relevant when working with minors. Privacy is greatly simplified if the data collected does not contain any personal details and cannot be traced back to specific students. The analytics system should ensure this by not collecting any personal information, and even then collecting only anonymized data. To meet this requirement and ensure that information collected is still useful for educators, anonymous tokens can be given to students to use them as pseudonymous identifiers in the game, and educators (and only educators) can choose to keep the correspondence between tokens and students.

With the steps and the experiences described, we consider that educators' tasks when using games in education can be greatly simplified at all stages: from the initial validation of games, to their actual use in classrooms in an effective and controlled way, up-to and including the automatic assessment of student learning based on their in-game actions. For all these steps, we consider that learning analytics data extracted from serious games is key to provide insight into students' actions when playing and simplifying educators' application of games in class.

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