A Tool Supported Approach for Teaching Serious Game Learning Analytics

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***Abstract*—This is an Innovative Practice Full Paper. Serious Game learning analytics can provide insight to improve both the learning process and the lifecycle of games. Due to the complexity and diversity of topics involved, from game design to implementation to tracing the user, teaching game learning analytics to engineering students is challenging. We have created a teaching approach built on an integrated set of tools to minimize the boilerplate setup and configuration typically required when building game learning analytics from disparate modules. Our approach relies on the combination of an authoring environment that eases the creation of adventure and location-based games, a standards-based interaction tracker, and a cloud-based analytics framework. In this environment, students can design and implement serious games with associated analytics models from the very beginning, allowing them to experiment from early on with analytics to improve their games' lifecycles. We have piloted this approach in two university courses for two years, where students prototyped serious games and then used analytics to understand how their users interacted with their games. The use of analytics helped our students to reflect on and refine their designs. While our approach can be applied with any tools, our authoring environment and analytics tools are available as open-source projects to facilitate development, prototyping, or testing of games with analytics.**

Keywords— serious games, analytics, teaching, higher education

I. Introduction

Serious Games (SGs) are videogames where the main purpose is not pure entertainment: it may be to teach, to change an attitude or behavior or to create awareness of a certain issue [1]. However, many, possibly most SGs are "black-boxes", interactive educational contents that, in the best of the cases, only report basic game information such as player's completion status or results (i.e., scores). Moreover, in black-box approaches there is no information about the player's behavior in the game, and the evaluation of the game or the measurement of its actual impact, if any, can only be performed through a costly, complex and ad-hoc external evaluation process, for example by using pre-post questionnaires.

Game learning analytics (GLA) is the capture and analysis of in-game player interactions to gain insights that can be used to improve the learning process [2]. GLA can also be used to improve the game lifecycle based on the actual evidence obtained from user behavior, instead of relying on simple metrics such as game completion status or end-game scores. From the learning process perspective, GLA can not only prove that players attain the educational objectives of a game; it can also help to identify issues in the learning process. In fact, we can draw a parallelism between GLA and game analytics, which have been used for a long time in the game industry. In Game Analytics, the focus is on game monetization and game quality capturing player's interaction is to analyze game performance, identify game issues and maximize player retention. In GLA, the focus is on the learning process, measuring the effectiveness of the game, the performance of students, and providing feedback for the learning process, such as where and how students get stuck in the game, and even pin-pointing possible measures or improvements.

However, effective use of GLA requires understanding not only of how to generate, collect and analyze in-game player interactions; but also how to integrate GLA as part of the whole lifecycle of SGs, and how to use that information to gain insights that can improve a very broad range of aspects, from the design to the effectiveness of the selected mechanics in specific educational deployments. Due to this breadth of scope, teaching GLA to students is a challenge.

The rest of the paper is structured as follows: Section II presents related work on GLA and SG's authoring tools with built-in analytics support, Section III outlines our proposed teaching approach, Section IV describes our results and, finally Section V provides some conclusions and future lines of work.

II. Related Work

We have not found specific methodologies to improve teaching of game learning analytics (GLA). We therefore present relevant work on GLA and game authoring tools to better contextualize our approach.

A. Game Learning Analytics

Understanding the SG lifecycle is key to effectively learn and apply GLA. This lifecycle includes design, creation, and deployment; and, to fully close the loop, the later analysis and decision-making process to improve the SG. Due to its educational purpose, the SG's main stakeholders are teachers and students, but researchers and developers can also benefit from GLA to guide their decision making. According to Chaudy, Connolly and Hainey [3], analytics are relevant from three perspectives: "the student's (how am I doing?), the teacher's (how are my students doing?) and the researcher's (how are the games used and are they useful?).". Chaudy [4] says that according to Powell and MacNeill [5] there are five potential purposes for LA: for learners to receive feedback on their learning and compare it with others', to predict a learner's need for additional support, for teachers to plan interventions, to improve current courses and develop new ones and for decision making at administration level. Additionally, Alonso-Fernandez et. al. consider that GLA can be used by SGs developers [6] in the game testing, validation and maintenance phases.

We can find some remarkable use-cases that have proven GLA to be useful in the game lifecycle. On its early stages, it can be used for validating games, as in the study from Calvo-Morata where GLA was used to prove the effectiveness of Conectado [7]. Another use case is to provide monitoring and custom assessment, such as in the case of the ENGAGE platform [8], where teachers used GLA to customize how to evaluate the students using the games; and it can even be used to even predict assessment itself as in [9]. These use cases, among other examples in the literature, can help solve the important problem of trust in the effectivity of games in education, making teachers less reluctant to use them [10], [11]. GLA can increase this trust by opening and providing insight into what would otherwise be black-boxes to stakeholders; and by enabling unobtrusive assessment and fostering evidence-based education.

There are two main approaches to GLA according to Chaudy, Connolly and Hainey [3]: information visualization (human-driven) and data mining (machine-driven). Alonso-Fernandez et. al. [6] noted that "the main purpose when analyzing data from SGs is assessment, […], or visually displaying performance information". They also concluded that the application of GLA information in the game lifecycle can help reduce cost and development complexity and provide a clearer measurement of the impact of SGs.

Despite GLA being a growing field, the usage of GLA is still limited when compared to the number of SGs being developed and studied. In 2014 Chaudy, Connolly and Hainey presented a Games Learning Analytics review showing only 14 relevant studies (including games and frameworks), with the oldest one from 2011 [3]. A review from Connolly et. al. published in 2016 [12] (extended from a 2012 publication [13]) found that only a limited number of educational games provide evidence of their effects. And only a small percentage of SGs included learning analytics at that point. However, a 2019 review from Alonso-Fernandez et. al. on SGs that applied data science [6] (visualizations, supervised and unsupervised models) to GLA showed that the number of GLA related publications has been steadily growing since 2011.

We consider that the additional complexity required to successfully apply GLA is one of the reasons for its limited usage. To use GLA it is necessary to create a Learning Analytics Model (LAM). This LAM contains the information that is needed to gain insight on the educational objectives and how they are processed, to allow later enable reporting, evaluation, and adaptation of the SG's lifecycle. GLEANER [14] proposes that this LAM can be then executed by a Learning Analytics System (LAS) that implements all the different processing steps, thus applying the LAM. The LAM and LAS are, in certain aspects, similar to Evidence Centered Design (ECD), as promoted in the ADAGE framework [15]; since ECD requires a tailored standardized process to create an analytics model (and system) that can validate game-specific competencies based on the in-game analytics tasks. However, the LAS is independent from any specific game and, in contrast to ECD, LAMs can be made flexible enough to re-use significant fragments, reducing costs and complexity compared to ECD. Reusable LAMs can be very useful, especially when coupled with educational standards and frameworks or authoring tools.

For this reason, Alonso-Fernandez et. al. [6] noted that "authors have pointed out a clear need for specific game learning analytics (GLA), where the use of standards to collect GLA data is desirable, as it allows the creation of open data sets in standard formats, such as xAPI [16], for research purposes, and simplifies results reproducibility and improvement, as well as testing of new techniques and integration of analytics as a module of larger systems". This approach is compatible with other works like the IDEFA framework [17], which works with event-stream data, using an external analytics processor with different levels of event interactions and progression marks.

The xAPI (Experience API) specification for Learning Analytics proposed by ADL is a flexible trace format that aims for flexibility and reusability [18]. This *de-facto* standard has consistently grown interest in both the educational and research communities, with most e-learning platforms supporting it or planning to support it. Traces in xAPI must include an actor, a verb, and an object, providing a flexible and expected format for very different purposes. xAPI not only covers data format aspects, but also defines a protocol to interact with a Learning Record Store (LRS) to submit and query xAPI statements [18]. Although the LRS protocol could be implemented in Learning Management Systems (LMS), it is usually implemented as an independent component, freeing the LMS not only of the task of managing the large amount of data that games can generate in real-time, but also offering a simple way to access the game results for both systematic analysis and assessment. GLA standards-based tools not only allow for a better interoperability, thus lowering costs, but also can simplify the learning analytics teaching by reusing existing components.

In conclusion, these standards can help the grow of GLA – and by some extent the acceptance of SGs – by allowing the creation of reusable LAS that can be constructed from smaller pieces, coupled with LAMs that can be both used generically for any SG and tweaked to fit specific SG objectives. Game authors can then focus on understanding and adapting a default LAM for their own purposes, using generic tools to add GLAs to their games, and reducing not only costs and complexity, but the learning curve as the GLA community and ecosystem grow.

B. Serious Games Authoring Tools and Learning Analytics

Teaching how to author SGs is also a complex task itself, and the choice of tools is critical for the viability of the course, as students need to develop SGs to fully understand their lifecycle. Although there are plenty of tools and platforms that could be used to develop SGs, in this section we have limited our analysis to those that both simplify development and include GLA.

On one hand we can find commercial tools for developing games such as Unity and Adventure Game Studio that have been proven as effective to develop SGs [19]; however, they usually present a steep learning curve when used to teach GLA. On the other hand, we can find tools like WEEV [11], which are simpler to use but much narrower in scope, and where educators take a more active role in the development process, which is designed to help them feel more comfortable while using educational games and even perform small modifications to better fit the games in their courses. By using a simplified authoring tool, we both reduce the SG authoring learning and creation effort.

There are several commercial SG authoring tools available. For example, ITyStudio[1] is a narrative game engine for use-cases such as behavioral simulations or training scenarios; and has integrated analytics within its own platform. Moreover, some of the most popular commercial educational authoring tools focus on narrative courses creation (not being strictly SGs authoring tools), such as Articulate 360[2] or Adobe Captivate[3]. Both have support interoperability standards through SCORM [20], and thus provide very limited analytics. One remarkable case that is especially relevant to the work presented in this paper is GameSalad[4] for education, used in courses to teach SG authoring to students. However, GameSalad does not include any GLA.

In addition, there several research and open-source game authoring tools. We found that many of those tools either did not provide support for learning analytics, such as the *Storytelling* Alice series [21] LAGARTO [22] or ARLearn [23]; or were discontinued, such as e-Adventure [24], Unigame [25] or Thinking Worlds [26]. We did find three tools that have publications in recent years and are available as open source:

- ENGAGE [27]: an open-source SG platform that supports many game genres and is focused on assessment, supporting quizzes, quests, monitoring of states and use of probabilistic models. With ENGAGE, developers create SGs that teachers can later modify through a web-based interface. In this interface, teachers can customize their assessment and learning analytics dashboards blocks including basic information, scores, interaction, and data mining.
- VEDILS [28]: a web-based application to develop virtual reality games compatible with many different external devices such as EEG sensors or hand trackers. Games can be easily designed using their web-based interface but to configure specific interactions it requires programming knowledge. According to [29] it has basic analytics support based on Google Tables and MongoDB.
- MAGIS [30]: an open-source AR focused engine that uses a domain specific language. It has a custom @analytics command to set up and send custom traces to an external server.

Both commercial and research tools offer simpler ways to develop SGs reducing costs and time and providing a more polished end-user experience with smoother learning curves. Commercial tools offer very controlled environments that can be key to guarantee the return on investment of the development of a SG, and provide a simple environment to monitor the learning process by limiting the assessment interoperability and potentially causing a vendor lock-in. In contrast, research and opens-source tools offer a more flexible environment that is normally paired with a more difficult analytics configuration. However, we think that ENGAGE [27] could be used for teaching GLA using our approach, as it can both simplify the game creation and offer a simple analytics and assessment management system, but we consider that a standards-based approach with xAPI is more beneficial in the long run, because it is the *de-facto* standard to represent learning analytics traces and also facilitates the usage and collaboration between special-purpose tools for each of the different aspects related to GLA (e.g. storage, analysis, visualization, etc.). However, we did not find any available integrated tools ready to use for a course on SG with GLA.

III. Teaching Game Learning Analytics

We have created a teaching approach built on an integrated set of tools, to minimize the boilerplate required to define and use game learning analytics (GLA) in serious games (SGs).

A. The tools

Our approach relies on the combination of an authoring environment that eases the creation of adventure and location-based games, a standards-based interaction tracker, and a cloud-based analytics framework (Fig. 1).

The uAdventure [31] open-source tool helps users with the creation of adventure and location-based SGs by providing simple authoring metaphor that focuses on educational aspects and does not require an extensive programming background. uAdventure is an evolution of a previous validated SG authoring tool called e-Adventure [24]. uAdventure maintains e-Adventure's functionality but built on top of Unity to take the most advantage of a professional, well-supported, and technically sound platform. uAdventure provides default GLA for the created games.

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[1] https://itystudio.com/
[2] https://articulate.com/360
[3] https://www.adobe.com/es/products/captivate.html
[4] https://gamesalad.com/

Fig. 1. The tools used in out courses that simplify the serious game (SG) lifecycle and the use of game learning analytics (GLA): uAdventure, xAPI Tracker, Simva and TxMon.

The out-of-the-box GLA uAdventure implements traces for all player related events in both narrative and location-based games and most of the system feedback. These events are traced using standard xAPI traces from the SGs profile [16] and location-based games profile [32]. The traces for narrative games include: player actions with elements, scene changes, conversation start and end, conversation choices, dialog fragment start, end and skipping and conversation choice selection; and game-state variable changes. The traces for location-based games include player interactions with real world elements such as: player movement and entering, exiting, and looking to regions or points of interest; and system events such as the discovery of elements hidden in the map. Additionally, creators can configure *completables* to obtain extra traces to determine the player progress and/or score in the game.

The *completables* system gives the creator a way to measure progress in the game of different things such as quests, stages or competencies that can be related with in-game events. To configure a completable, the user must relate the different progress milestones with specific key points of the player interaction or game state. Additionally, to the user created completables, uAdventure represents the game itself as a completable that will start when the game starts and end once the game ends or all the completables are completed and can be used to measure the overall player progress and score in the game.

To gather and analyze the different traces generated by the uAdventure game, the Simva, "SIMple-VAlidator", [33] platform complements the ecosystem to help manage GLA. Simva is an open-source project, that offers an integrated solution that provides storage for xAPI traces but also contributes with SG validation by managing validation studies, including user enrollment, groups management, support for surveys for pre and/or post testing, and providing access to real-time analysis and visualization. In Simva, the user can see user progress and scores, monitor the traces and access analytics dashboards. The Simva platform also includes TxMon, "Traces Monitor", an extensible python-based data science environment that provide additional analysis.

Both tools can be easily connected by using the Simva extension for uAdventure [34], which includes a simple and resilient tracker that implements the xAPI for SGs analytics profile [16], and also simplifies the Simva setup with the use of a step-by-step wizard. Using both uAdventure and Simva, students can design and implement a game with associated analytics in uAdventure and then experiment with Simva to access actual user traces in real-time, learning how these analytics can be used to improve the lifecycles of their games.

B. Course Design

Using this combination of tools our students can focus on implementing the SGs and use the available analytics from early-on and during each of the different phases of the development of their SGs, without having to deal with low-level implementation aspects or GLA infrastructure setup.

The course structure for this approach consists in three parts: i) an introductory part, ii) a SG development part, and iii) a GLA workshop part (Fig. 2).

The introductory part lasts for five weeks (20 hours total) and introduces the students to the SGs theory and design from three perspectives: theory, practice, and experimentation. For the theory, students will learn about SGs, game genres, gamification, educational objectives, game design documents and the basics of GLA. To complement the theory, students will experience with some SGs, analyzing some SGs selected by the teacher and researching their own SGs to show them to their classmates in the class. To contrast all this theory and experimentation, the students receive some real-life advice from industry experts in several masterclasses, describing their experiences in development and use of GLA. Finally, students are divided into groups of three.

After the introduction student groups implement SGs on their own during another five weeks period (20 hours total). This small timespan is one of the reasons to choose a tool with a smooth learning to create the SGs, allowing the students to focus on the design and implementation of their SGs from an educational perspective. uAdventure lets students create games using a high-level interface based on narrative concepts. The tool also includes a user startup guide, a complete in-depth user manual with eleven examples, and several extra examples and step-by-step tutorials. In our course we introduce uAdventure from two points of view: adventure games and location-based games; each including an introduction to the game genre and a guided, 4-hour example.

During this period, students designed and implement at least two SGs prototypes which allow them to experiment with different ideas and scenarios. For this reason, we recommend creating adventure games, since they provide a proven narrative environment that can be applied to many different use cases [35]; and location-based (or augmented reality like) games, which let students develop games that use real-life elements in their teaching. However, any VR/AR/Simulation game would fit very well into this part. For each game, students must create a game design document that includes their learning objectives along with the game plot and puzzles in the specific game format fitting uAdventure's capabilities.

During the final part, students are introduced to GLA concepts and design, including GLA-related tools, in a two-hour session. They must then implement GLA in their games and test those games with their classmates using the tools during the rest of the six remaining weeks (totaling 28 hours). For the concepts, we include GLA design and xAPI traces and how these traces can be used to evaluate the games including xAPI for SGs profile [16] and for location-based games experimental profile [32]. This approach is supported because we use uAdventure as a trace generator along with the tracker and Simva as to collect traces (LRS) and manage experiments.

In uAdventure, both SG and location-based profiles are supported and traces from those kinds of interactions are tracked out-of-the-box or with minimal configuration. Since one of the most important use cases for GLA is to measure progress and scores [14] *completables* are explained and enforced in this stage. uAdventure's completable view allows students to indicate in-game milestones, such as interactions with elements, scenes, or even specific game-states, which represent progress; and optionally to link those milestones to the game's educational objectives.

Once their games are completed, including analytics, students ask their classmates to play, and then review the results using Simva as the supporting GLA framework. This exchange allows students to access GLA traces in real-time and receive feedback from users with prior experience in SGs. Prior to using Simva to manage experiments, students receive a brief introduction to both the basic Simva interface and the uAdventure-Simva experiment wizard; and participate in a live experimental session to understand how traces are generated in the uAdventure platform. We would also like to test our student's games with actual users in real environments, but this is not always possible, since it depends heavily on schools being interested in deploying the games in their classrooms at a very short notice.

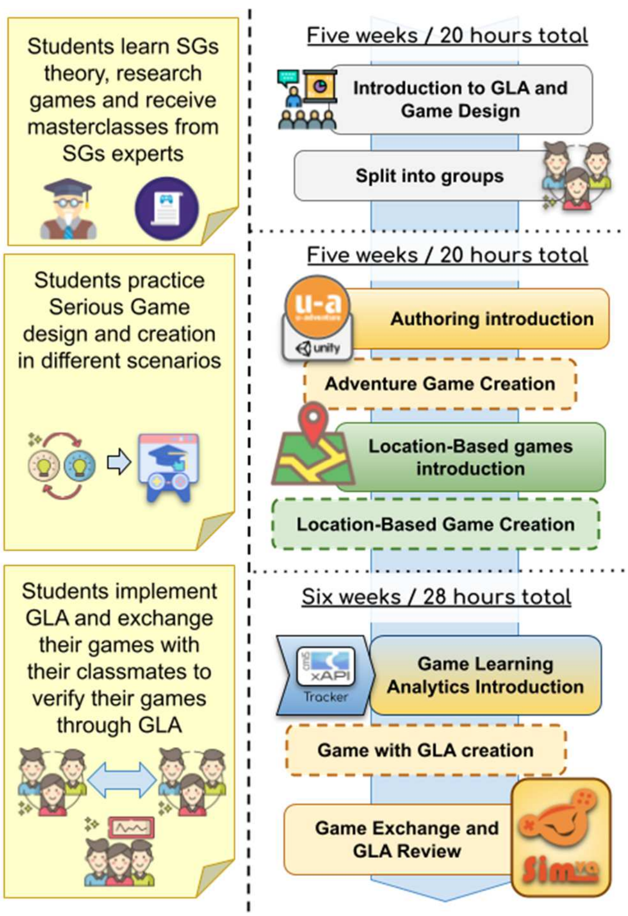

Fig. 2. Our course scheme including three periods: i) theory, research, and expert masterclasses; ii) serious game (SG) authoring of different genres; and iii) Game Learning Analytics (GLA) workshop, including, how to set them up in games, and then testing their SGs and GLA with classmates.

We have piloted this teaching approach in two university courses: the serious game and e-learning modules. The courses are part of the Video Game Development Degree and the MSc. in Computer Science respectively at the Complutense University of Madrid.

IV. Use cases

A. *Previous teaching experiences*

Prior to developing Simva, we piloted our approach by using uAdventure for learning analytics in two different workshops (two and four hours respectively) [36]. In these workshops, students were able to configure and extract progress-related traces from their uAdventure games in both xAPI and CSV formats. However, due to the complexity of the previously mentioned configuration process, students were unable to use Learning Analytics dashboards and test their games with either colleagues or actual target users.

With Simva and the step-by-step wizard included in uAdventure, we have solved this issue reducing the complexity of the setup and providing easy access to experiment control panels, LA dashboards and participant access codes.

B. *Serious Games module*

Our approach has been used in the SGs module for two years. This module is taught in the first semester and in the 2020-2021 academic year had nine students divided into three different groups. It is organized in 28 two-hour sessions, including both theoretical and practical lessons, plus 6 extra unsupervised sessions with teacher support –totaling 68 hours of work.

The introductory part teaches students the basics of SGs, including an introduction, applications, gamification, and game design documents. Then, students had to analyze different cherry-picked SGs (e.g., OregonTrail, BadNews, Foldit) and research on their own SGs to present to their classmates using the CitizenScienceGames.com website as an entry point. To finalize the introduction, a total of three experts in SGs gave them masterclasses with advice, showcasing their own projects.

As previously mentioned, the SGs development part consisted in the implementation of two different SGs per group including a narrative SG and a location-based SG. This implementation phase had a total of six lessons, including: i) a theoretical uAdventure lesson with a live example implementation, ii) a networking and brainstorming session, iii) a formal presentation of their ideas, iv) two to three supported development sessions, and v) a final presentation including a prototype and a video. A total of six different games were implemented, both narrative games and location-based games. Some of these projects were later extended for the final GLA workshop part.

In the GLA workshop part students extended three of their previous developed prototypes and included GLA using the built-in set of tools in uAdventure and the uAdventure and Simva connection. The three final projects included at least basic analytics. The use completables to track the players overall progress within the game. In general, all the groups created a one-to-one relationship between the narrative chapters and the completables. For instance, all groups added an introduction or tutorial completable and completables for the different puzzles in their games. In addition to the out-of-the-box GLA, one group implemented tailored traces to represent the different states of the puzzles using the xAPI tracker built into uAdventure. Their traces represented initial states and the interaction with each button in the different game puzzles.

The students succeeded in both building SGs with uAdventure including GLA using the Simva platform and then exchanged the games with their classmates. With the use of GLA, the students were able to validate the extent to which: 1) their classmates can complete their games, 2) they can make progress in their playthroughs and, 3) they can complete and score in each game's completables. After this workshop, students analyzed their results and made a presentation showcasing their projects, the data they obtained, and the next steps they would make to their projects. With this last presentation, students consolidated their knowledge of the usability of GLA in the game's lifecycle.

1) Narrative Game Projects

During the first SG development, students implemented purely narrative SGs. This year, the games explored three different topics: i) computational thinking, ii) sexism at work and iii) internet scam awareness for old and disabled people.

The computational thinking game was organized as an escape room. The game tells the story of a mansion where paranormal activity is occurring. The player must solve different mini games that require one or more computational thinking skills including: algorithm design, abstraction, pattern recognition and problem breakdown. It was extended with more detailed analytics for the final module project.

The game about sexism at work consists of a job interview where the player is asked frequent questions that women can be asked (such as pregnancy related ones) and in the end of the game it will be revealed that the player is a woman. As a final project it was extended with a second part represents the first day of work where the player must choose who to befriend and will receive different questions and comments during the day that will raise awareness to the player about sexism.

The last narrative game about internet scams awareness for old and disabled people and is designed as a short game that helps the player identify common signs of scam such as unexpected prize emails, you-have-a-virus ads, or mobile phone subscriptions.

2) Location-Based game projects

During the second SG development, students implemented location based SGs. The games explore three different topics: i) treasure hunts to promote computational thinking, ii) showcasing the collection of different small museums at the college and iii) civil war remains at the college campus.

The treasure hunting with computational thinking puzzles game was based on the same principles as the first computational thinking game but using narrative puzzles instead of mini games. The players had to find a hidden treasure solving four different puzzles in a nearby park.

The college museums are small, but very rich and diverse. This game proposed a gymkhana where, for each museum, players had to answer questions with clues found in the museum, embracing exploration and investigation by searching real-life locations.

The last location-based game about the civil war tells the story of both sides as they clashed in the campus, which was caught in the front line. In the game, the player will explore four different key locations of the battleground seeing pictures and learning about the civil war. To entertain players while they go from one key building to the next, the players will find characters and news from the civil war time. This game was also extended for the final project.

C. *E-Learning module*

The second experiment was performed over a span of 3 weeks, starting in late 2020, to students of a MSc. course on e-Learning. The 7 enrolled students were introduced to the uAdventure game authoring tool, asked to design a simple conversation-driven adventure game on a topic of their choice, and requested to design a full experiment, including in-game analytics, to validate their games.

This section of the course encompassed 6 sessions in total, with two sessions per week. Weekly sessions were half online, introducing new concepts for 1 hour, and half face-to-face, dedicated to practical tasks, with students working and presenting in pairs using laptops for 2 hours. The sessions in each week were structured as follows: Session 1 introduced SGs and adventure games, with hands-on tutorial creating a serious game using uAdventure. Homework: build a minimal conversational game on a topic of your choice. Session 2 required students to design experiments in SGs, with a Q&A session to iron out problems in the initial games. Homework: design pre-post questionnaires on a topic of your choice to validate your game on that topic. Finally, session 3 was focused on analytics in SGs, connecting the games to Simva-enabled experiments that could be carried out over the winter break. Homework: test each other's games and propose analytics dashboards on which to analyze results from your own games.

Although technical problems and time constraints prevented us from carrying out the experiments envisioned in the 3rd week, the students of the course, divided into 4 groups (3 pairs and one student working on his own), succeeded in building (very simple) analytics-enabled conversational adventure games to teach concepts in 4 different topics, with accompanying experimental designs that were readily uploaded to Simva. The students did not have to learn how to integrate analytics with their games, configure an analytics server to receive and process them, or worry about identifying game players against an analytics server – as all these steps were automated by Simva; yet the steps were easy to inspect once configured. In this sense, the teacher responsible for the course, which is also one of the authors of the present paper, plans to continue using uAdventure + Simva in future courses.

V. Discussion and Conclusions

Teaching serious game analytics can be a challenge due to the amount of knowledge to fit in the courses. By using a tool assisted approach, we simplified much of the boilerplate-but-complex technical aspects allowing for students to focus on the game creation and the use of analytics to better understand the game lifecycle from its early design stages until their testing stages. Automating non-essential parts of a course can greatly improve usability and satisfaction; this approach is especially relevant in courses where programming is needed but not required to understand the main concepts, and it is frequently used in AR and Machine Learning course.

Game learning analytics (GLA) data allows student to contrast the game results and improve it in the different phases. Our results show that students were able to create serious games and use GLA to improve the game quality. For instance, finding educational design mistakes, implementation issues or unexpected user behaviors that hinder game applicability but that were not possible to identify during the quality assurance phase. Therefore, the use of analytics helped our students to reflect on and refine their designs.

Our authoring environment and tracking tools are open-source and freely available for developing, prototyping, or testing games with analytics (at github.com/e-ucm). They can be freely used in other similar courses and even beyond university teaching. Both our data tracker and our analytics framework can be integrated with other authoring tools and games, reducing the costs of providing GLA support to other authoring tools.

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