Technical Ecosystem For Game Learning Analytics Applied To Serious Games

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Abstract

The term "serious gaming" generally refers to any use of digital games for purposes other than entertainment, including training simulations and social critique games. Today, the term is even used for game-based approaches to collaborative solving of complex problems. However, most academics tend to use the term "serious games" to refer to the use of digital games for educational purposes. To advance in the study of evidence-based serious games in authentic learning contexts in schools, we propose the systematization of game-based learning by integrating a data-cycle based game learning analytics model using xAPI 2.0.0 IEEE standard. This will allow for larger experiments with non-intrusive user evaluation and the inclusion of what has been termed stealth assessment in serious games. The systematization part of that approach would promote a greater use of analytics since its implementation would be simpler by relying on xAPI standard as a user interaction capture language and on the possible reuse of modules: tracker, LRS, and analysis modules. This would permit us to capture more data that could later be analyzed in a traditional way or perhaps by fine tuning a generative AI system. This paper presents the current work on the game analytics infrastructure and the related systems to simplify serious games validation (including the support for pre-post validation surveys).

Keywords

xAPI, serious game, analytics, data-cycle based, game learning analytics

1. Introduction

Using videogames in the learning process brings different benefits such as provide an immersive learning environment [1], allowing for a more active students´ role, breaking the 10-minutes attention span [2], and represent risk situations in a safe environment. Due to these benefits, different fields have started to design and develop games for purposes other than entertainment (e.g., educational purposes). Those games designed for purposes beyond entertainment are called Serious Games (SGs). SGs have been successfully used in education, healthcare, communication or politics [3].

Despite the benefits, the use of SGs in class also has barriers that limit its use. Some of these barriers are scarcity of validated SG, difficulty in adapting the SG to the curricula, the old hardware of the school [4]. There are other obstacles for the generalization of SGs in mainstream education such as that the professor needs to know what his students do and what they learn, as SG acts as a black box. To know what the students do, the teacher needs tools to help them know what's going on. And to trust the games they use, they must have proven their

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effectiveness, so developers also need collect interaction data and make studies with the target users.

But tracking user interaction has become a limiting factor for the integration and selection of format of analytics in SG and for the use of those SGs in classes due to the lack of resources to evaluate and track students' progress [5]. To resolve this, we use Learning Analytics (LA) techniques. LA is the collection of data from learning activities to improve some aspects of the educational process. When applied to games, it is also referred to as Game Learning Analytics (GLA) [6], [7]. GLA comprises the collection, analysis and visualization of data collected from player interactions in a serious game to obtain information for multiple purposes (game validation, player evaluation) and that may be of interest to multiple stakeholders (game designers and developers, students, teachers). GLA breaks the game black box model to obtain information via reports with information and feedback while and after, students play, **Figure 1**by collecting information on how the games are being played and compare player interactions (**Figure 1**). GLA allows check if the games have the desired learning effects allowing teachers know their students' progress, but also, allowing developers validate the effect of their SG.

For the validation purpose, our GLA infrastructure also include support for the user pre-post evaluation surveys that allows us to capture information about the actual game effects in the students.

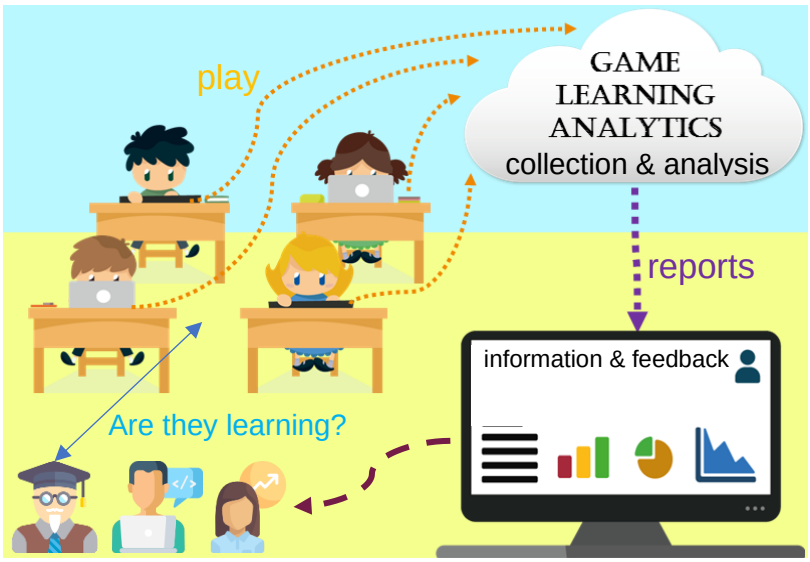

Figure 1 : Game Learning Analytics (GLA).

To collect that user interaction data, GLA system need a data model to represent the game information. In this aspect, the use a standard format not only simplify the collection, but also streamline the subsequent analysis of the collected data as we can use all toolkits that exist and that use this standard. After analyzing different standards that exist like SCORM or IEEE Experience API (xAPI) 2.0 standard [8], we decided to use xAPI – as a practically human natural language comprehension and for its use in education ton online courses MOOCs to capture the learning process – to implement into the e-UCM technical ecosystem for GLA to track data in SG. Each xAPI statement contains three main fields, describing an actor, a verb, and the object

of the action. Additional information such as extensions can be included; and statements typically include a timestamp to capture the time at which the action occurred.

The Experience API for Serious Games (xAPI-SG) profile [9] defines a set of commonly used verbs and their associated types, including: interacted, and used, to capture interactions with game objects, game items and other characters (NPCs or enemies); initialized, progressed, and completed, to capture the start, progress and completion of the entire serious-game or significant part of it (e.g., within a level); and accessed, to capture screen or area changes.

The xAPI-SG standard allows collecting GLA interactions from serious games using an xAPI-based vocabulary representing the most common interactions present in these games [10]. Each player interaction is captured as an xAPI-SG trace (referred to as a statement), usually represented in JSON, like in Figure 2.


```
{
   "id": "8b895fd2-86e4-44ec-9058-f908a79f7857",
   "actor": {
      "account": {
         "homePage": "https://simva.e-ucm.es",
         "name": "jgut"
      },
      "name": "jgut"
   },
   "verb": {
      "id" : "https://w3id.org/xapi/seriousgames/verbs/accessed"
   },
   "object" : {
      "id" : "https://simva.e-ucm.es/activities/6630b46b5042570425a07dc5/Menu",
      "definition" : {"type" : "https://w3id.org/xapi/seriousgames/activity-types/area" }
   },
   "result" : {
      "extensions" : { "https://w3id.org/xapi/seriousgames/scene" : "menu" }
   },
   "context": {
      "registration" : "006c89f7-24c1-4acd-a729-51b779f22503",
      "contextActivities" : {
         "category" : [
            {
               "id" : "https://w3id.org/xapi/seriousgame"
            }
         ]
      }
   },
   "version": "2.0.0",
   "timestamp": "2024-04-30T09:08:53.723Z"
}
```


Figure 2 : xAPI-SG statement example.

This xAPI-SG data can be stored and analyzed by giving feedback and visualizing this data to give the teacher a better understanding. The goal is to provide a better toolkit for the use in class from the teacher to give him more information about the learning process of his students. In this paper, we present the objectives and the methodology to achieve this goal.

2. Objectives

The GLA system has been schematized and modelized [11] like show Figure 3. This system is composed of a collector (in red) – that collect the data, an aggregator (in blue) - that aggregate and store the data, a reporter (in green) – that report the data into dashboard, an evaluator – that evaluate the data - and an adapter (in green) – that adapt the data and give feedback.

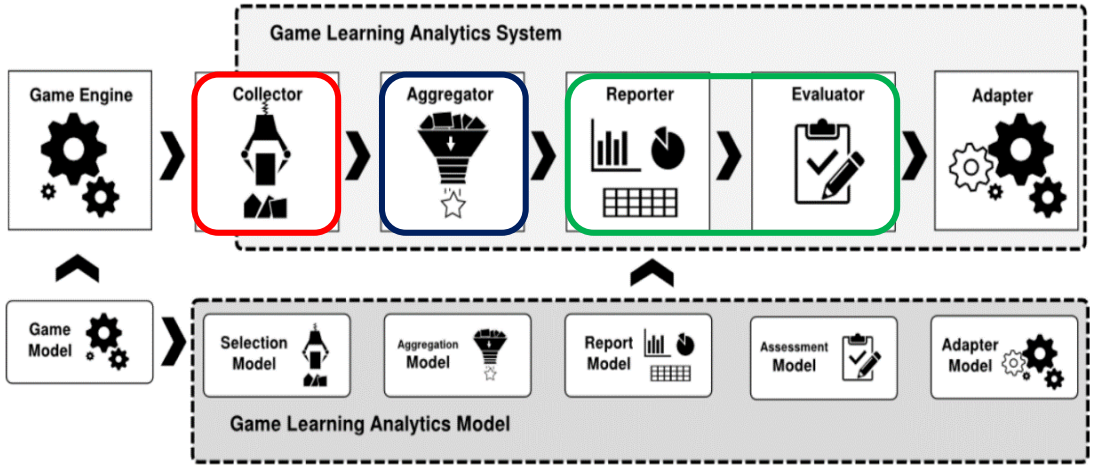

Figure 3 : GLA System.

The principals' objectives of this work are to improve this GLA system in their different part:

- *COLLECTOR*: **Studying the use of standards for user interaction tracking: xAPI profile for serious games.** The use of standards is aimed at facilitating interoperability and the possibility of developing research methodologies for GLA transferable to real scenarios.

- *AGGREGATOR*: **Systematize data analysis processes in serious games in an open and standardized way using the IEEE xAPI standard** [12]. This allows to improve different aspects of the game lifecycle from design to implementation and validation and contributes to validate the effectiveness of games in a more scientific and data-cycle based way (serious evidence-based games) and all this applied especially to games to teach at early stages in schools.

- *REPORTER and EVALUATOR*: **Study the analysis of interaction and survey data using AI techniques and predictive language models**, applying them to student learning. If the teacher asks a question to the generative IA about this xAPI data, would the IA be able to answer in a natural language.

3. UCM technical ecosystem for Game Learning Analytics

Systematizing GLA requires **reliable software** to manage the traces. In this project, I will work with, and improve, the e-UCM ecosystem of tools for LA - composed of SIMVA, XASU and T-Mon. I will systematize and validate an **Analytics Toolkit** to include into this ecosystem.

3.1. XASU: xAPI Analytics Supplier - Tracker for the recollection of data

The Xasu (xAPI Analytics Supplier) is a Unity asset developed by the e-UCM group [13] that simplifies use of xAPI LA from Unity with straightforward cmi5 support. It can be considered as a **collector** in the GLA system as he can send data to other tools.

Xasu is a tracker, which, when integrated into a game, can send and/or store player interactions for later analysis. This is especially important when proving that a serious game is effective at its goal, be it teaching, training, or changing the players' perspective on real-world issues. As a tracker, Xasu simplifies the work of serious games developers (or of any application using LA) by providing both simple tracking and multiple quality-of-life utilities with which to configure the collection of xAPI traces in a flexible and robust way. Xasu is also included in U-Adventure Unity plugin and already tracks some xAPI statements by default.

3.2. SIMVA : SIMple VAlidating of serious games using pre-post surveys.

SIMVA [14], [15] is a tool that helps Serious Games (SGs) developers / researchers to validate the effectiveness of SGs and to facilitate the application of LA in SGs [16]. It can be considered as an ***aggregator*** in the GLA system as he can store the data into the platform.

Like any other educational tool, the traditional way of evaluating the effectiveness of the tool is through experiments that require pre-post tests. Usually this is done on paper or, in the best-case scenario, electronically, but in the end these tests are disconnected from the experiments themselves. SIMVA can receive traces as data from games developed with XASU to store it into a S3 bucket in SIMVA platform.

Moreover, SGs open new opportunities of applying a stealth assessment approach to evaluate players' performance [17], [18]. Usually, this approach is implemented based on analytics that are gathered during the gameplay.

To be precise, SIMVA tool aims to simplify the possible issues:

- Before the experiments:
  - Managing users & surveys
  - Providing anonymous identifiers to users
- During the experiments:
  - Pre Test-Game-Post Test (cf. Figure 4)
  - Collecting and storing surveys and traces data (xAPI-SG)
  - Relating different data from users (GLA, tests)
- After the experiments:
  - Simplifying downloading and analysis of all data collected.

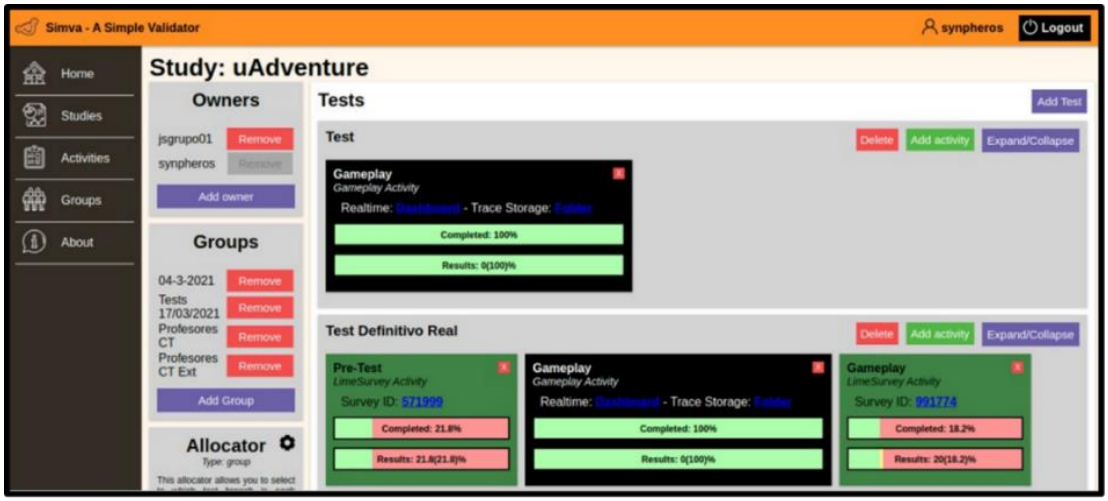

Figure 4 : SIMVA Study example.

3.3. T-Mon: Visualize data.

The e-UCM group has started working on open source to simplify GLA analysis (and the phD candidate was one of the programmers) creating the exploratory tool T-Mon [19] that provides the first step by displaying a default set of visualizations based on the fields available in the xAPI-SG standard. It can be considered as a ***reporter*** in the GLA system.

All visualizations included in T-Mon are game-independent like the progression of players in **Figure 5** and the response of each players per questions in **Figure 6**; that is, no game-specific data is required to create them. This allows us to perform such exploratory analysis instantly for any given game if the interaction data collected follows the xAPI-SG standard and implies a cost reduction at the time of the first analysis [20].

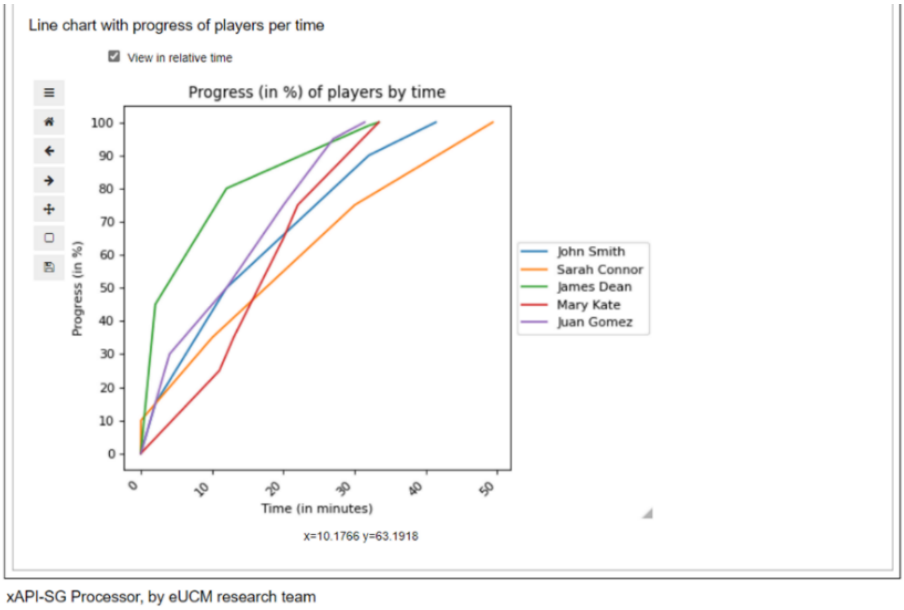

Figure 5 : Line chart showing the progression of players during the serious game.

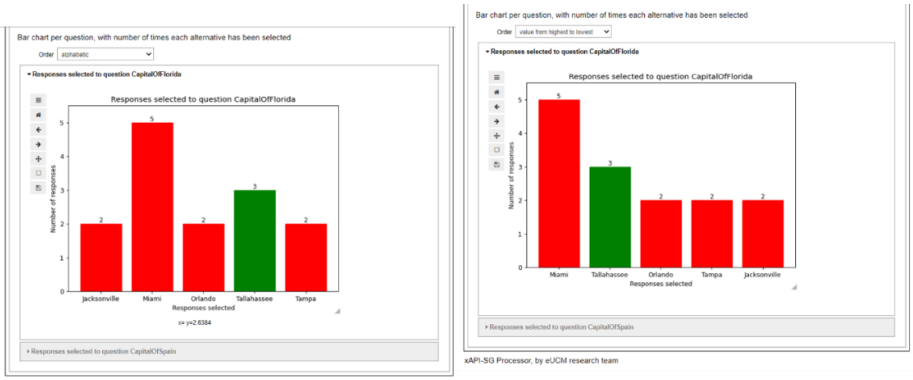

Figure 6 : Bar chart showing the response of players to some questions during the serious game.

4. Methodology

After studying the ecosystem of tools for LA of e-UCM team, updates and improvements to this platform will be made. Based on the work on T-Mon, a GLA model and tool will also be developed to provide recommendations and information about student learning in a game about programming and computational thinking. This tool will apply educational standards, such as xAPI, to represent the information.

The starting methodological approach of this work will follow an iterative and incremental process showed in **Figure 7** - where software development, user validation studies and tests will be performed - after 2 first steps. This will start with a systematic review of the literature and tools that exist for learning analytics, as well as the most widely used educational standards in this field will be done. After the SIMVA platform and telemetry tools of the e-UCM research team will be studied and updated.

The next iterative step is to apply the developed model in real scenarios. The new tools will be evaluated through tests with actual users, after the beta testing in the lab we will apply in a real class context in a school in Madrid. Based on the results, the models and tools will be improved and more robust to be applicable to other serious games in other real-world domains (e.g., health).

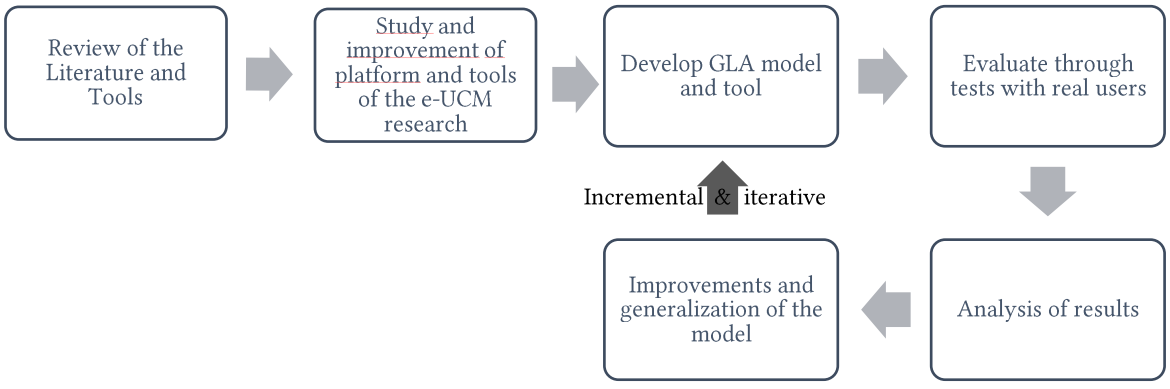

Figure 7 : Methodology Sequence

5. Future work

The future work on SIMVA would be upgrading infrastructure of SIMVA external tools (Keycloak, Limesuvey, Minio, Kafka) and fix the integration of SIMVA as a LTI tool and as a LTI platform. This will allow integrate Simva with Moodle to be able to use the same authentication of the school in SIMVA and to access to SG connected with the e-UCM ecosystem. In this way we avoid the need for students to have numerous accounts, and we will have the interaction traces identified with their institutional account.

The future work on Xasu would be to check validity with standard IEEE xAPI 2.0 and check the data can be imported into a standard Learning Record Store (LRS) outside SIMVA for the xAPI data to be valid and to be sent into a LRS where the data can be analyzed with other tools. Those parts have already started and it's in progress.

The future work on the GLA model and tool, based on T-Mon, would be adding more default visualizations and giving resumed text feedback about the student interactions and learning. We also want to explore the use of AI to query interaction data using natural language, taking advantage of the features of the xAPI standard and its natural language approach (subject, verb, object), to facilitate access to information and giving understandable reports about students' learning. That part hasn't started.

6. Conclusion

This work is a step to create more a more robust GLA ecosystem that allow to improve the use of serious games in real contexts. This process will simplify the validation of SG and obtain more evidence of SG use that allows us to gain insight about students learning. Also, this work can help to generalize the use of xAPI in educational games as the IEEE Standards xAPI 2.0 specification would greatly simplify GLA implementation and adoption simplifying the reuse of existing tool developed for educational purposes.

But full implementation of GLA in real class scenarios is still complex and fragile. Real time GLA is too complex, costly and error prone (i.e., it is quite common to have internet and hardware problems). This is the reason we are focusing more on the SG validation and on the capture of evidence of SG effects instead on the real-time GLA. Finally, it is important to notice that always the ethics in experimental design should drive the GLA process and all times in necessary to comply with all legal requirements (e.g. EU GDPR)

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