

Leveraging xAPI for Multimodal Learning Analytics Data Standardization in Serious Game Validation

Julio Santilario Berthilier¹[0009-0003-2520-507X], Antonio Calvo-Morata¹[0000-0001-8701-7582],
Iván Martínez-Ortiz¹[0000-0001-6595-5690] and Baltasar Fernández-Manjón¹[0000-0002-8200-6216]

¹ Universidad Complutense de Madrid Av. Complutense, s/n, Moncloa, 28040 Madrid, España
jsantila@ucm.es ; acmorata@ucm.es ; imartinez@fdi.ucm.es
; balta@fdi.ucm.es

Corresponding author: Julio Santilario Berthilier

Abstract. Evaluating serious games (SGs) in education is a complex and resource-intensive process, limiting the number of serious games formally validated with large user populations. Evidence-based evaluation is challenging because it requires diverse data (e.g., interaction logs, user feedback) obtained through controlled experiments to accurately assess game impact. To address the complexity of working with heterogeneous data sources and the absence of standardized formats, the IEEE e-learning standard xAPI offers a structured yet flexible framework for collecting and storing learning analytics to allow researchers to unify gameplay analytics and survey data. Combining data from different sources within the same standard as xAPI opens the door to the construction of larger databases for the study of SG learning and to a multimodal analysis, something that has been difficult to achieve until now. This work describes an analytics framework that supports this approach by integrating xAPI for SG experimental designs, telemetry tracking, surveys, and data storage. This infrastructure enhances data ownership, privacy (including pseudonymization), and interoperability, enabling large-scale studies and multimodal analysis. The methodology contributes to reproducible research, validating SG's educational impact and fostering a sustainable data ecosystem for evidence-based research. This approach enhances data management efficiency and reinforces the research community's capacity (simplifying compliance to legal/ethical standards such as EU GDPR) to produce rigorous evidence regarding the educational impact of games, validating them as effective pedagogical tools. Overall, this multimodal learning analytics framework fosters the development of a more interoperable and sustainable data ecosystem that underpins evidence-based educational research with SG.

Keywords: xAPI, multi-model learning analytics, serious game validation, survey data, xAPI application profile.

1 Introduction

Serious games are innovative educational tools that combine engagement and learning within a specific context, promoting active and meaningful learning [1] by enabling

students to face challenges and interactively construct knowledge in a safe and supportive environment. Serious games have demonstrated their potential in various educational aspects, including problem-solving, cognitive skill development, and understanding complex concepts in diverse contexts (e.g. military, business, health). [2] However, their application in classrooms remains limited due to several factors, such as integration into the curricula or actual deployment in classes. [3] We consider that a crucial aspect for the generalization of serious games is their validation as effective educational tools. [4]

Evaluating the educational impact of serious games (SG) remains a key challenge in educational technology. The diversity of data sources, metrics, and methodological approaches makes it difficult to compare SG results and general findings, particularly when most SG are validated with small student samples. Experimental studies often combine diverse multimodal information, such as gameplay interaction logs, before (pre) and after (post) surveys, and performance measures, which are typically captured in different formats and systems. [5] This heterogeneity limits the ability to conduct integrated analyses, compare results, and assess the influence of SG on player behavior and learning outcomes—an essential step for validating their effectiveness.

The pre-post method is the most used approach for evaluating serious games. It provides a structured way of measuring the impact on learners' knowledge or skills by comparing their performance before (measuring initial knowledge, skills or awareness) and after (measuring effective changes) the educational intervention (i.e., in this case playing the serious game). These surveys are often composed of multiple-choice questions (MCQs), case studies, problem-solving tasks, or open-ended questions, depending on the skills and knowledge the game seeks to develop. The same questions are generally used in both the pre-survey and post-survey to ensure a direct comparison of results. Current survey tools such as LimeSurvey¹, SurveyMonkey², and Google Forms³ facilitate the creation of surveys, allow participants to respond, and enable researchers to collect data in CSV, JSON, or Excel formats. In addition, these data from surveys are currently combined with user interaction data that allows for analysis of player behavior during the gaming session. The user interactions data can be collected in real time or at the end of the session in the form of log files, and there is a wide variety of formats available to represent this information. Some game platforms provide analytics support (e.g. Unity3D). [6] However, this support is mostly oriented towards improving economic aspects (e.g., user revenue) and it does not support integration with pre-post data.

Therefore, despite the potential of serious games to provide valuable information about user interaction and learning, significant challenges remain. Some of these challenges are full data ownership and the lack of standardization in data analytics, which limits the integrated analysis of information from different sources. Analytics platforms usually impose restrictions on analytics data that may jeopardize data ownership or complicate compliance with data privacy regulations (e.g., the EU GDPR). To address

¹ <https://www.limesurvey.org/>

² <https://www.surveymonkey.com/>

³ <https://workspace.google.com/products/forms/>

this problem, we propose a solution that involves establishing a standardized data format enabling the analysis of comprehensive datasets regardless of their initial origin — whether survey responses or serious game interactions. The solution also adds features that enable data anonymization at the beginning while maintaining the correlation of the same user across the whole experiment. The approach of having data from multiple sources merged into a single source would facilitate the analysis, comparability and combination of information, while also enabling the application of more effective learning analytics methods based on user interaction data. It seeks to overcome current limitations and implement innovative solutions that maximize the value of data collected in educational and learning contexts.

In this context, we consider that the IEEE e-learning standard xAPI (Experience API) [7] offers a promising solution by providing a simple and structured, yet flexible and extensible, format for multimedia learning analytics data collection. xAPI represents each user interaction as a trace with an actor–verb–object structure. These traces can be stored in a Learning Record Store (LRS) or other interoperable repositories, supporting integration across platforms and applications. An LRS is a specialized system designed to collect, store, and manage data about learning experiences from various sources, such as courses and informal learning activities. As xAPI does not require a closed environment or dependence on a specific Learning Management System (LMS), it facilitates its adoption in serious games, research settings, and hybrid learning environments. Moreover, xAPI’s ability to capture real-time, multi-source data makes it particularly well suited for the comprehensive evaluation of serious games.

In this article, we propose an analytics framework based on the xAPI standard to unify the data format of multimodal serious game learning analytics data, including both gameplay telemetry data and pre-post survey data. The principal objective is to simplify the integration, analysis, and comparison of serious games by using a common standardized model.

2 IEEE xAPI e-learning Standard

xAPI⁴ (Experience API) [8] is an IEEE Standard to capture and share human performance data, enhancing learning analytics and education that was initially promoted by the Advanced Digital Learning (ADL) initiative under the US Department of Defense to cope with all the analytics interoperability needs of their heterogeneous systems and to facilitate the procurement of different solutions for training purposes that use xAPI as *lingua franca* between them. xAPI provides a standardized format for the collection of multimodal learning analytics data. Each xAPI statement contains six main fields describing the actor, the verb, the object of the action, a timestamp to capture the time at which the action occurred, the xAPI version used and the context with a context activity and a registration identifier to identify the same session. Additional optional information called extensions can be also included. For instance, for games this allows user actions to be expressed as 'Player X did Y thing at Z point in time, and in V context',

⁴ <https://adlnet.gov/projects/xapi/>

facilitating understanding of student interactions and progress in different activities. Each user interaction is captured as an xAPI statement (also called xAPI trace), usually represented in JSON.

xAPI is a flexible, scalable and interoperable data standard whose traces are stored in databases called Learning Record Store (LRS) [9]. xAPI is only a standard format for capturing user interaction events but does not define a common vocabulary that should be defined by each specific application or use. To address these limitations and foster the reusability of xAPI data, the xAPI Application Profiles were introduced. An xAPI Application Profile allows to define a standard-based common vocabulary for traces in a specific domain or type of application (e.g. video analytics) and all the systems using an application profile will produce interoperable analytics data (those systems “speak” the same language, and the events are compatible with reusable dashboards and analysis). xAPI application profiles are not part of the xAPI standard but are built on top of it, by allowing the definition of vocabularies should be defined and agreed upon by a community of users (e.g. the community of Serious Games). To help identify which application profile a particular trace belongs to, xAPI standard defines an identifier that appears in the context field of the xAPI traces. As illustrated in **Fig. 1**, a xAPI-SG interaction trace is presented.

xAPI use in educational platforms, like Learning Management Systems [10] and MOOCs [11], to capture complex, distributed, and informal learning experiences, has illustrated its capacity to unify and analyze information from diverse sources, thereby transcending the constraints imposed by isolated formats such as CSV or JSON. However, xAPI use in the serious gaming domain is still limited, but we consider it can contribute to improve the quality and facilitate the interpretability of the learning analytics data.

```
{
  "id": "8b895fd2-86e4-44ec-9058-f908a79f7857",
  "actor": {
    "account": {
      "homePage": "https://simva.external.test",
      "name": "68527b8d6cdba20023369437_xztr"
    }
  },
  "verb": { "id": "http://adlnet.gov/expapi/verbs/initialized" },
  "object": {
    "id": "https://simva.external.test/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",
  "stored": "2024-04-30T09:08:55.895Z",
  "authority": {
    "homePage": "https://simva.external.test",
    "name": "mylrsmanager"
  }
}
```

Fig. 1. xAPI-SG statement example

3 Analytics framework based on xAPI

To facilitate SG validation through multi-modal data collection and analysis, we propose using the xAPI standard for data representation and we provide an open-code framework to support it. This e-UCM analytics ecosystem is open-code software architecture which supports technical aspects such as the SG gameplay data capture to more scientific aspects such as the support for the SG validation experimental design. This framework is composed of several interconnected systems used by different stakeholders with different use cases shown in **Fig. 2A**:

- Developers can develop serious games and integrate analytics, allowing xAPI traces to be sent and analyzed to obtain information that can be used to improve and/or validate the game.
- Teachers can easily deploy games in the classroom, allowing them to obtain interaction data and conduct surveys to evaluate the effectiveness of the game and its effects on students.
- Students can access the games and activities posted by their teachers, using pseudonymous accounts.
- Researchers can register design experiments with different educational that the system will manage (including the pseudonymized data integration from various sources).
- Data scientists can create and customize default visualizations based on the xAPI profiles.

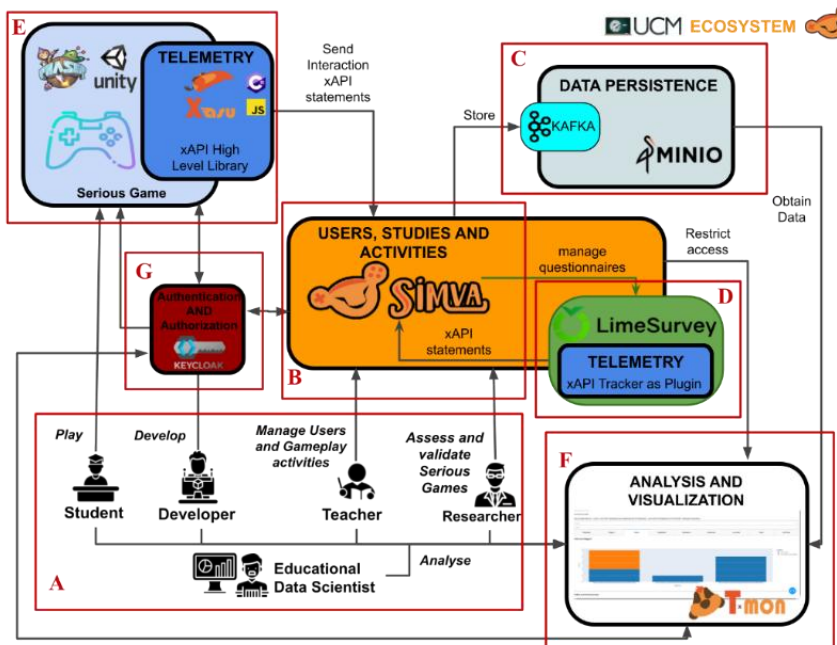


Fig. 2. e-UCM ecosystem

This architecture uses Dockerized containers that bring easy deployment and enable the delegation of the most critical functionalities to reliable and scalable platforms. So, it is a modular scalable and interoperable architecture composed of specialized tools (both proprietary and developed by third parties – e.g., LimeSurvey, Keycloak), supporting extensibility and module replacement without modifying the overall architecture. The main modules of this architecture are:

- SIMVA, shown in **Fig. 2B**, the core of the system and a web platform for experiment and users’ management. It consists of a frontend and a backend with an LRS system (i.e., traces database) to store xAPI interaction data (**Fig. 2C**) and a REST API that allows connection to other modules.
- LimeSurvey⁵, a well-known and widely used open-source platform to create and carry out user surveys. In our case, LimeSurvey enables collecting data surveys for the user evaluation comparing the status/knowledge of users before and after experimentation sessions.
- Trackers, a set of telemetry libraries for collecting Serious Games gameplay traces and LimeSurvey user answers, shown in **Fig. 2D** and **Fig. 2E**. These libraries allow interaction data to be represented in xAPI format and sent to the server where it will be stored and analyzed (allowing to pseudonymously relate traces with surveys answers).
- T-Mon, shown in **Fig. 2F**, dashboard and analysis python-based tool which enables the analysis and visualization of xAPI data to obtain relevant and understandable information about the interaction data stored in the LRS. It includes default analysis based on the xAPI-SG vocabulary that can be extended with ad-hoc game-dependent analysis.
- Keycloak⁶, shown in **Fig. 2G**, an open-source Identity and Access Management System (IAM) with OpenID support, It allows different stakeholders with different authorization levels across the system using a single user identifier from SIMVA web platform to access other modules such as games, LimeSurvey, or T-Mon.

Each component is integrated through a xAPI data bus, allowing them to operate independently while contributing to a shared data infrastructure. Each component will be described in more detail in the following sections.

3.1 SIMVA

SIMVA, (from Simple Validation tool) [12], [13] is the core of the system showed in **Fig. 2B** and is a web platform for managing and supporting different SG experimental designs and user evaluation settings (including support for pseudonymization by using random codes assigned to participants).

The platform allows the management of SIMLET. A SIMLET consists of groupings of learning experiences that are related in some way (e.g., by the same game, a shared set of users, or a specific project or course). Within a SIMLET view, a user can create

⁵ <https://github.com/limesurvey/limesurvey>

⁶ <https://github.com/keycloak/keycloak>

multiple sessions, which may share the same set of participants. Sessions that share users support the design of courses in which multiple serious games are employed, whereas sessions involving different user groups enable A/B testing or experiments with control groups.

Sessions are defined as sequences of activities that are executed consecutively. SIMVA module provides an API that controls whether a specific activity has been completed or not, thereby enabling or preventing progression to the next configured activity from the same session. The activities that can be used within a session are:

- Game activity allows offsetting a game for the session and the collection of data from users enrolled in that session.
- Survey activity allows adding, configuring, and using a survey, assigning it exclusively to the users of the session.
- Manual activity allows configuring a generic activity; the teacher or researcher in charge must manually indicate whether a user has completed the activity or can let his students indicate themselves when they complete the activity.

Users' assignment to sessions is performed through the creation of user groups, where one or more groups may be assigned to a single session. Groups can be created such that each participant is assigned a unique random identifier, without requiring personal information such as names or email addresses. These identifiers are generated at the time of group creation as randomized character strings, which function both as access code for the SIMLET and as identity identifiers linking all the user data within a session (e.g., gameplay traces and survey responses).

Additionally, SIMVA enables the generation of a printable sheet containing user group identifiers (**Fig. 3** for distribution during the session, allowing teachers to map student names to their corresponding identifier and to reuse this information later on. These identifiers are used to link the interaction data of the same user across different activities within the same SIMLET and serve as a pseudonymous user identity.

Group: Test Group					
No.	Name	Code			
1		gnos	gnos	gnos	gnos
2		xtxw	xtxw	xtxw	xtxw
3		bugu	bugu	bugu	bugu
4		toin	toin	toin	toin
5		kixr	kixr	kixr	kixr

Fig. 3. Printed sheet of random identifiers for pseudonymized users.

SIMVA uses Keycloak as a specialized module, acts as an identity management system that creates and manages these pseudonymous user identities. It ensures that each participant has a unique identifier, which serves as a login credential for accessing SIMVA activities. The same random identifier is used across multiple data sources to link participants' data without exposing personal information. This approach ensures

that all data points can be cross-referenced using the pseudonymous identifier, facilitating comprehensive analysis while maintaining user privacy. The use of random identifiers instead of personal data helps with the compliance of ethical and legal regulations such as the General Data Protection Regulation (GDPR) by minimizing the risk of exposing sensitive information. In addition, SG Profile is designed to avoid the collection of personal data, and users are explicitly informed of this policy within the platform before creating any game activity. They are required to confirm compliance with ethical and data protection requirements by selecting a verification checkbox, thereby ensuring that no personal information is transmitted as part of the game interaction data.

As a use-case, Fig. 4 illustrates the configuration of one session added from Fig. 4A named “My Session” displayed in Fig. 4B composed of three activities. The session represents a typical pre-post experimental design for evaluating a serious game, where the gameplay activity (i.e., students play the SG) is situated between two surveys (i.e., pre and post serious game surveys) shown in Fig. 4C. Five users displayed in a table in Fig. 4D participate in the session and are assigned random identifiers that serve as pseudonymous user identity. First, users take the pre-survey. Then, they play the game. Finally, they take the post-survey.

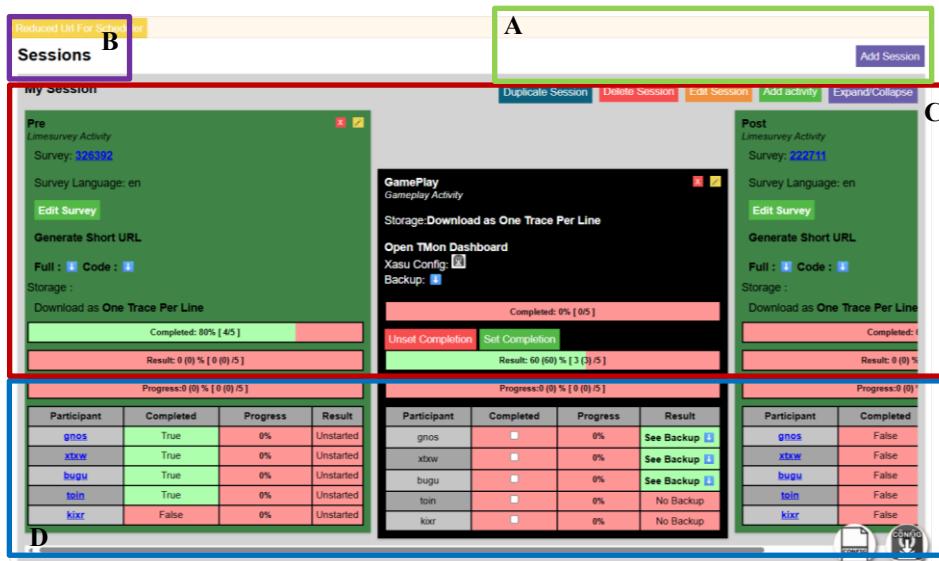


Fig. 4. Simple SIMVA SIMLET composed of a session addition (A), a list of activities (C) within a session (B) with a dashboard for each participant (D)

In our infrastructure, we defined an LRS (i.e., user interaction database) endpoint in the SIMVA API for each activity that receives xAPI interaction data and stores it on the configured server. This allows us to have the data separated for each activity and stored on the server of the desired organization. This provides total data analytics ownership granting access only to the privileged users (e.g., researchers) who created and managed the session.

SIMVA provides high-level tracking of session activities and visually reports the completion percentage of the current activity in real time in the **Fig. 4C** and **Fig. 4D** through the SIMLET web platform. For instance, SIMVA receives interaction data from LRS endpoints to analyze each xAPI trace with the verb values “initialized”, “progress” (with a percentage result), or “completed” (with a completion boolean) to update the SIMVA dashboard.

3.2 Serious Games Trackers

The framework provides libraries (trackers) for sending interaction data in xAPI format, using the xAPI application profile xAPI-SG, defined in the context with the category <https://w3id.org/xapi/seriousgame>. [14] To enable integration with data from other learning activities or surveys, the generated xAPI traces must be both coherent and complete. Coherence refers to semantic consistency across statements and the use of terms (vocabulary) defined in the xAPI-SG application profile. When a verb clearly matches an action in the profile and the object uniquely identifies an element whose definition is also included, completeness ensures that all information needed for analysis and replication is explicitly recorded in the trace. This information includes an ID, actor, verb, object, timestamp, context, version, and, optionally in some cases, a result.

These libraries also connect through Keycloak for user login and use the SIMVA API for activity management. Currently, we have developed two trackers for Unity (Xasu [15]) and for JavaScript [16]. New trackers for different technology can be added to SIMVA (currently a new tracker for Godot game engine is being developed).

Trackers allow capture data on the participant's interactions with a game, such as clicks, moves, and time when user change scenario or level, like the trace shown in **Fig. 1** that is both coherent and complete (i.e. this is also called gameplay traces). Our trackers will send traces into SIMVA LRS endpoint but can be configured to send data to any other LRS system (e.g., ADL LRS [17], Veracity LRS [18] or TRAX LRS [19]).

3.3 LimeSurvey

As previously mentioned, one of the problems with analytics platforms that collect game interaction data is that they are not integrated with survey systems. We address this issue by integrating LimeSurvey. LimeSurvey is an open-source web-based application for creating and publishing surveys and questionnaires. However, there is a data integration challenge. As LimeSurvey (and other survey platforms) represents data in a proprietary format and responses need to be linked with gameplay data. To unify the data format, we have developed a special module that converts survey responses into the xAPI format at the time of submission, allowing interaction data from games and survey responses to be represented in the same format. The data integration of survey answers and gameplay traces is addressed by sending survey data using the participants pseudonymous identifiers.

The module specializing in this format conversion is the xAPI Tracker for LimeSurvey. [20] This LimeSurvey plugin incorporates a tracker capable of collecting and sending xAPI survey interaction data to SIMVA survey LRS endpoint. And that survey

traces are sent using Keycloak participant's pseudonymous identifiers. Therefore, xAPI LimeSurvey tracker sends data as xAPI statements to SIMVA in real time, while the participants answer the survey.

xAPI data generated by this LimeSurvey plugin uses the application profile defined for SCORM. [21] Instead of creating and agreeing with the SG community about a new application profile for surveys, we used a proven vocabulary for representing and managing assessments, making it a suitable fit for our survey requirements. The SCORM xAPI profile is characterized by its use of specific context categories and verb identifiers that can be repurposed to accurately capture the lifecycle of a survey, from initialization to completion, as well as participant's responses to questions. By leveraging this existing application profile, we ensure that the data transmitted during surveys adheres to a consistent format, enabling seamless integration with existing tools and platforms while maintaining the coherence and interpretability of the collected information. In our LimeSurvey plugin, this xAPI SCORM application profile is identified in each trace using the context field with the category "https://w3id.org/xapi/SCORM" and we use four types of traces to represent different types of user interaction with the survey: initialization, to know when participant start a survey; progress, to know the position of the participant in the survey; responded, to know the answer to the question with the context of the question and terminated, to know when participant terminate the survey.

Type 1: Initialization. This interaction indicates when a participant starts interacting with the survey. The mandatory fields of the statement for initializing a survey are displayed in the partial statement in Fig. 5. The field "object.id" should distinctly and uniquely identifies the survey.

```
{
  "verb": { "id": {"http://adlnet.gov/expapi/verbs/initialized"},
  "object": {
    "id": "<url of the survey platform>/<surveyid>",
    "definition": { "type": "http://adlnet.gov/expapi/activities/assessment" }
  }
}
```

Fig. 5. Partial statement for initialization of the survey

Type 2: Progressed. This interaction indicates the participant's current position in the survey, and its value is within the interval [0, 1] and increases when completing a page/section of the survey. The mandatory fields of the statement for progressing through a survey are displayed in the partial statement in Fig. 6. The field "object.id" should distinctly and uniquely identifies the survey.

```
{
  "verb": { "id": {"http://adlnet.gov/expapi/verbs/progressed"},
  "object": {
    "id": "<url of the survey platform>/<surveyid>",
    "definition": { "type": "http://adlnet.gov/expapi/activities/assessment" },
    "result": { "score": { "scale": "<float between 0 and 1>" } }
  }
}
```

Fig. 6. Partial statement for progressing through the survey

Type 3: Responded. This interaction indicates the answer to a survey question. When the participant completes a page/section of the survey, all the participant responses are sent at the same time as progress interaction xAPI traces. Those questions can be of different types like question choices, numeric or free text as shown in **Table 1**.

Table 1. Types of questions in LimeSurvey and the corresponding interaction type in xAPI and possible responses values

Interaction code	Interaction description in LimeSurvey	xAPI Interaction type chosen	Possible responses values
5	5-point choice (radio)	choice	Choices
B	Array (10-point choice)	likert	Scale
A	Array (5-point choice)	likert	scale
I	Array (Flexible Labels) dual scale	likert	scale
E	Array (Increase, Same, Decrease)	likert	scale
:	Array (Multi Flexible) (Numbers)	likert	scale
:	Array (Multi Flexible) (Text)	likert	scale
C	Array (Yes/No/Uncertain)	likert	scale
F	Array (flexible labels)	likert	scale
H	Array (flexible labels) by column	likert	scale
X	Boilerplate question (no direct xAPI equivalent, treated as text)	other	-
D	Date	fill-in	-
G	Gender (single choice)	choice	-
U	Huge free text	long-fill-in	-
I	Language switch (treated as text)	other	-
!	List (dropdown)	choice	choices
L	List (radio)	choice	choices
O	List with comment (choice + text)	choice	choices
T	Long free text	long-fill-in	-
K	Multiple numerical input	numeric	-
M	Multiple options (checkboxes)	choice	choices
P	Multiple options with comments (choice + text)	choice	choices
Q	Multiple short text	fill-in	-
N	Numerical input	numeric	-
R	Ranking	sequencing	choices
S	Short free text	fill-in	-
Y	Yes/No	true-false	-

For example, as shown in **Fig. 7**, for an open-ended question about feedback on the game, the type would be “long free text” while for a list of questions with a scale with custom labels with the first one about the user perception of the game, as shown in the **Fig. 8** would be the “array with a flexible labels”.

The screenshot shows a LimeSurvey interface. At the top left is the LimeSurvey logo. At the top right, it says 'Language: English - English'. The main heading is 'Opinion'. Below that, there is a question: '*What did you think about the game?'. Underneath the question is a large, empty rectangular text input field.

Fig. 7. LimeSurvey long free text open question (LimeSurvey type code: T)

The screenshot shows a LimeSurvey interface for a survey titled "Perception". The question is "How much do you agree with the following statements?". A legend defines the 7-point scale: 1 - Totally disagree, 2 - Strongly Disagree, 3 - Disagree, 4 - Neither disagree nor agree, 5 - Agree, 6 - Strongly agree, 7 - Totally Agree. Below the legend, a table shows the statement "The game lasts too long" with radio buttons for each scale point from 1 to 7.

Fig. 8. LimeSurvey array with flexible labels question (LimeSurvey type code: F)

The mandatory fields of the statement for an answer to a question through a survey are displayed in the partial statement in Fig. 9. The field “object.id” should distinctly and uniquely identifies the question.

```
{
  "verb": { "id": {"https://w3id.org/xapi/verbs/responded"},
  "object": {
    "id": "<url of the survey platform>/<surveyid>/interactions/<questionid>",
    "definition": {
      "type": "http://adlnet.gov/expapi/activities/interaction",
      "interactionType": "<interactionType>"
      "choices": / "scale": [
        { "id": <identifier>, "description": {"<language-code>": "<response-in-the-language>" }},
      ]
    },
    "result": { "response": "<response answered>" }
  }
}
```

Fig. 9. Partial statement for answer to a question into a survey

The interactionType field within the xAPI trace represents the types of LimeSurvey questions. Possible values are true-false, choice, fill-in, long-fill-in, matching, performance, sequencing, likert, numeric or other. Table 1 describes the possible interaction types with the xAPI interaction type chosen used in the LimeSurvey plugin. For example in Fig. 7, the interaction type chosen would be “long fill-in”, while for the Fig. 8, the interaction type chosen would be “likert” interaction type.

The answered data is available in the xAPI trace in the field “result.response” defined by the field “object.definition.interactionType”. For example, for fill-in or long-fill-in, it would be a text, while for numeric, it would be a number. The Fig. 10 shows an xAPI statement indicating the response of pseudo anonymized user 68527b8d6cdba20023369437_xztr to the question shown in Fig. 7 in a survey hosted at “https://limesurvey.simva.external.test/292378”. The question, titled “Opinion1”, asks, “What did you think about the game?”. This action occurred on December 1, 2025, at 11:43 UTC. The participant answered the long-fill-in question with the response “The game was pleasant to play, and I learned some new things about coding.”.

```

{
  "actor": {
    "account": {
      "name": "68527b8d6cdba20023369437_xztr",
      "homePage": "https://simva.external.test"
    }
  },
  "verb": {"id": "http://adlnet.gov/expapi/verbs/responded"},
  "object": {
    "id": "https://limesurvey.simva.external.test/292378/interactions/Opinion1",
    "definition": {
      "name": {"en": "Opinion1"},
      "description": {"en": "What did you think about the game?"},
      "interactionType": "long-fill-in",
      "type": "http://adlnet.gov/expapi/activities/interaction"
    }
  },
  "result": {"response": "The game was pleasant to play, and I learn some new things about coding."},
  "context": {
    "contextActivities": {"category": [{"id": "https://w3id.org/xapi/scorm"}]},
    "registration": "e12cf18e-4341-4cff-a268-087ceb1bc0af"
  },
  "id": "407f3fa9-c928-4c6e-8c8e-d23b908b8fb7",
  "timestamp": "2025-12-01T11:43:14Z",
  "version": "2.0.0",
  "stored": "2025-12-01T11:43:17.833Z",
  "authority": {
    "name": "mylrsmanager",
    "homePage": "https://simva.external.test"
  }
}

```

Fig. 10. Example of an xAPI trace of a LimeSurvey answer to a long free text open question. It also include the question which simplify the later analysis.

When the value of the interactionType is “likert” or “choice”, the value of the field “scale” or “choices” respectively is an array showing the semantics in the xAPI statement of the LimeSurvey question's possible responses. The semantic of one response is composed of one identifier of the response and a description in same language used in answering it. Assigning the identifier facilitates direct articulation with the possible response and enables interpretation without external knowledge of the survey data, meaning that there is no need for additional data from outside the xAPI trace data. Since responses can be collected in different languages, the “result.response” field contains the identifier of the selected response and not the description which its value varies in different languages. This approach facilitates comparing responses across different languages in the same survey. The **Fig. 11** illustrate an xAPI statement answer of the response to the LimeSurvey question in **Fig. 8**. The pseudo anonymized user 68527b8d6cdba20023369437_xztr responded to a Likert-scale survey question. This survey is hosted at “https://limesurvey.simva.external.test/292378”. The question, titled “Perception1 [long]” asks, “The game lasts too long”. The response occurred on December 1, 2025, at 11:13 UTC, and the selected response is 1, which as it is a likert interaction type, which corresponds to the value “1 — Strongly Disagree” on the 1–7 Likert scale. Having all this data directly in the xAPI trace enables the question to be replicated within another study without any external knowledge of this xAPI data.

```

{
  "id": "5f47c149-e4d4-4947-98ec-5a6ad2b15633",
  "actor": {
    "account": {
      "name": "68527b8d6cdba20023369437_xztr",
      "homePage": "https://simva.external.test"
    }
  },
  "verb": {
    "id": "http://adlnet.gov/expapi/verbs/responded"
  },
  "object": {
    "id": "https://limesurvey.simva.external.test/292378/interactions/Perception1/long",
    "definition": {
      "name": { "en": "Perception1 [long]" },
      "description": { "en": "The game lasts too long" },
      "interactionType": "likert",
      "type": "http://adlnet.gov/expapi/activities/interaction",
      "scale": [
        { "id": 1, "description": { "en": "1 - Strongly disagree" } },
        { "id": 2, "description": { "en": "2" } },
        { "id": 3, "description": { "en": "3" } },
        { "id": 4, "description": { "en": "4" } },
        { "id": 5, "description": { "en": "5" } },
        { "id": 6, "description": { "en": "6" } },
        { "id": 7, "description": { "en": "7 - Strongly agree" } }
      ]
    }
  },
  "result": { "response": 1 },
  "context": {
    "contextActivities": {
      "category": [ {
        "id": "https://w3id.org/xapi/scorm"
      } ],
      "parent": [ {
        "id": "https://limesurvey.simva.external.test/292378",
        "definition": {
          "type": "http://adlnet.gov/expapi/activities/assessment"
        }
      } ]
    },
    "registration": "e12cf18e-4341-4cff-a268-087ceb1bc0af"
  },
  "timestamp": "2025-12-01T11:13:29Z",
  "version": "2.0.0",
  "stored": "2025-12-01T11:14.028Z",
  "authority": {
    "homePage": "https://simva.external.test",
    "name": "mylrsmanager"
  }
}

```

Fig. 11. Example of an xAPI trace of a LimeSurvey answer to array with flexible labels question. In this case a Likert7 Selection and it includes not only the answer but also all the context of the question

Type 4: Terminated. This interaction indicates the end of the survey. The mandatory fields of the statement for terminating a survey are displayed in the partial statement in **Fig. 12**. The field “object.id” should distinctly and uniquely identifies the survey.

```

{
  "verb": { "id": { "http://adlnet.gov/expapi/verbs/terminated"},
  "object": {
    "id": "<url of the survey platform>/<surveyid>",
    "definition": { "type": "http://adlnet.gov/expapi/activities/assessment" },
    "result": { "completion": "true" },
  }
}

```

Fig. 12. Partial statement for terminating the survey

All this modeling and coding of LimeSurvey questionnaires in xAPI format is integrated into the e-UCM analytics ecosystem to automate data capture in a IEEE xAPI compliant format. During a SIMLET session, the xAPI LimeSurvey tracker will detect the participants’ interactions with surveys such as initializing, answering questions and completing. This integration facilitates the effective xAPI SCORM application profile multimodal learning analytics for surveys. This methodology has been implemented with LimeSurvey solution, but it can be generalized to other platforms following a similar approach.

3.4 T-Mon

T-Mon (Trace Monitor) [22] is a dashboard and analysis tool currently under development. T-Mon processes data in the xAPI-SG format by loading, analyzing, and presenting xAPI-SG statements (traces) through a default set of visualizations that provide a comprehensive overview of the dataset, as illustrated in Fig. 13.

At present, the integration of multimodal analysis—combining gameplay data with pre- and post-survey responses—is currently in progress. While users can access a basic set of visualizations for xAPI-SG traces, the functionality supporting the combined analysis of game (xAPI-SG) and survey (xAPI-SCORM) data is not yet fully implemented.

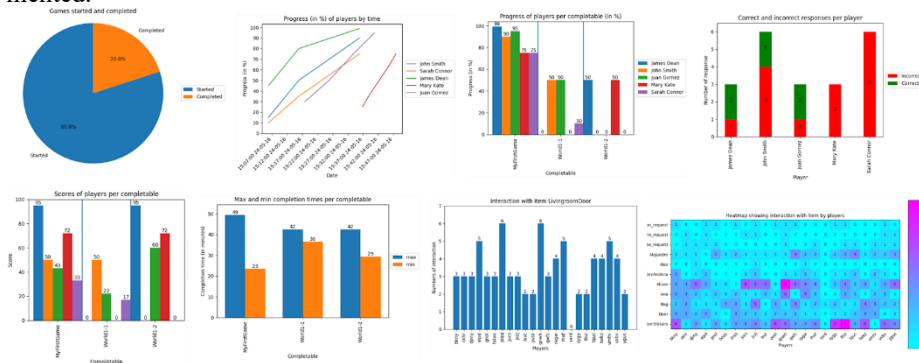


Fig. 13. T-Mon default analysis and visualization for serious game xAPI-SG learning analytics data

By leveraging the verb-object structure of the xAPI format, T-Mon enables the creation of configurable visualizations based on identifiers associated with each action and

object. This approach facilitates the generation of default visualizations for gameplay xAPI-SG traces, such as average playing time, user progression, and game-completion events. Furthermore, because all user interactions are captured in xAPI-SG, the system allows for the creation of additional ad hoc analyses tailored to the specific needs of researchers, students, or teachers.

The ability to independently analyze pre- and post-survey data using the xAPI-SCORM format represents a significant methodological advancement for data integration in SG evaluation. This standardized representation supports consistent analysis across different surveys, ensuring direct comparability of results without requiring manual data transformation. Until now, T-Mon worked with pre- and post-surveys data to filter users, for example by displaying only those who completed all questionnaires or who provided specific responses to selected questions. More advanced analyses linking gameplay data with questionnaire responses required customized, case-specific processing. By adopting a common data format across all interaction sources, T-Mon can now identify trends by relating in-game behavior to questionnaire responses, enabling more integrated and generalized analyses. Furthermore, the characteristics of the xAPI format open promising opportunities for future work, particularly in the application of Gen AI to analyze and correlate data from multiple sources associated with the same user.

In addition, the integration of SIMVA sessions within the same framework will support comprehensive data comparison both within individual sessions and across multiple sessions (using the same pseudo anonymized user identifiers). This capability is particularly valuable for longitudinal studies, where monitoring changes over time is essential.

4 Conclusion

We present a standardized framework for validating serious games and learning experiences using the standard xAPI to represent users' interactions in learning activities (i.e. learning analytics). This tool ecosystem has a clear impact on the SG validation process by systematizing it and automating it, by reducing the technical requirements, manual interventions that are error-prone. The simplification of deployment and validation of serious games in real environment through this analytics ecosystem facilitates the justification of their use in the classroom, as teachers can rely on evidence of their actual impact.

The adoption of e-learning standards such as xAPI enhances interoperability, improving process efficiency while contributing to more sustainable data ecosystems. This standardization supports better resource management and promotes information interoperability, including data reuse across platforms and contexts. Furthermore, it supports the development of SG evidence-based practices, promoting informed decision-making and reliable results. By adopting xAPI in their SG research initiatives will enhance not only their data quality but also their multimodal learning analytics integration obtaining a more transparent working environment. Furthermore, the implementation of the xAPI trackers ensures consistency of the standard format data across

different systems clients (LimeSurvey, SG), leading to more efficient and reproducible outcomes.

Additionally, the framework is modular and facilitates the integration of different learning systems through xAPI, enabling communication and complementarity between educational platforms. For example, the same pseudonymous tokens can be used in different activities to ease both xAPI multimodal analytics and GDPR compliance. This integration enhances data collection efficiency and simplifies data integration for better comprehensive analysis, resulting in accurate reports for informed decision-making. Moreover, it promotes interoperability and ensures greater coordination in monitoring and evaluating learning outcomes, offering a holistic vision that benefits educational institutions.

In conclusion, the implementation of this framework underscores the importance of xAPI standard as a key tool for integrating diverse learning systems. It not only streamlines operations but also supports future research, driving innovation and efficiency in education and research practices.

5 Limitations and Future Work

In general terms, there is a limitation in integration with any SG or survey system that is the need to access the SG code and to adapt to the different traces or information sent by the SGs.

Based on the xAPI-SG application profile we provide default analysis for simple SG aspects (e.g., average playing time). In the future, the intention is to develop default analyses and visualizations for the most common data sets considering also the pre-post experiments, especially for multimodal data (survey and gameplay data). This would permit us to correlate game performance with survey responses and allow us to draw conclusions about the effectiveness of serious game intervention and improve future studies.

We will continue to add features to the e-UCM ecosystem, with advanced analytics tools integrating this aspect of Multi Model Learning Analytics in T-Mon. The intention is also to study the use of Gen AI to improve GLA analysis and to improve the understanding of the SG supported educational activities (using both xAPI-SG and xAPI-SCORM data). This will also open the door to simplify the interaction with the learning analytics data in natural language or for getting textual insights about the educational experience.

It is necessary to continue with the validation of the platform. Although it has already been used in multiple serious gaming experiments, its usability and deployment need to be improved to simplify third-part adoption.

Acknowledgements. This work has been partially funded by the Spanish Ministry of Education (PID2023-149341OB-I00) and by the Telefónica-Complutense Chair of Digital Education and Serious Games.

Disclosure of Interests. The authors have no competing interests to declare that are relevant to the content of this article.

References

- [1] J. Rugelj, "Serious Computer Games Design for Active Learning in Teacher Education," *Lecture Notes of the Institute for Computer Sciences, Social-Informatics and Telecommunications Engineering, LNICST*, vol. 161, pp. 94–102, 2016, doi: 10.1007/978-3-319-29060-7_15.
- [2] F. Bellotti, R. Berta, and A. De Gloria, "Designing Effective Serious Games: Opportunities and Challenges for Research," *International Journal of Emerging Technologies in Learning (IJET)*, vol. 5, pp. 22–35, Nov. 2010, doi: 10.3991/IJET.V5ISI3.1500.
- [3] Y. Zhonggen, "A Meta-Analysis of Use of Serious Games in Education over a Decade," *International Journal of Computer Games Technology*, vol. 2019, no. 1, p. 4797032, Jan. 2019, doi: 10.1155/2019/4797032.
- [4] H. Schoenau-Fog, "The Player Engagement Process – An Exploration of Continuation Desire in Digital Games," *DiGRA Digital Library*, vol. 2011, no. 1, Jan. 2011, doi: 10.26503/dl.v2011i1.540.
- [5] "Deep Learning-Based Multimodal Affect Detection for Adaptive Learning Environments - ProQuest." Accessed: Jan. 27, 2026. [Online]. Available: <https://www.proquest.com/open-view/8de51738c54fd2abc42b818f91592a2b/1?pq-origsite=gscholar&cbl=18750&diss=y>
- [6] H. Zhong and J. Xiao, "Apply technology acceptance model with big data analytics and unity game engine," *Proceedings of the IEEE International Conference on Software Engineering and Service Sciences, ICSESS*, vol. 2015-November, pp. 19–24, Nov. 2015, doi: 10.1109/ICSESS.2015.7338998.
- [7] "IEEE to Standardize xAPI v2.0 as an International Standard | ADL Initiative." Accessed: Dec. 05, 2023. [Online]. Available: <https://adlnet.gov/news/2021/10/20/IEEE-to-Standardize-xAPI-v2.0-as-an-International-Standard/>
- [8] "xAPI 2.0 IEEE Standard / About · GitLab." Accessed: Jan. 30, 2026. [Online]. Available: <https://opensource.ieee.org/xapi/about>
- [9] P. Berking, "Choosing a Learning Record Store (LRS) Advanced Distributed Learning (ADL) Initiative," 2016.
- [10] K. Kitto, S. Cross, Z. Waters, and M. Lupton, "Learning analytics beyond the LMS: The connected learning analytics toolkit," *ACM International Conference Proceeding Series*, vol. 16-20-March-2015, pp. 11–15, Mar. 2015, doi: 10.1145/2723576.2723627.
- [11] M. H. Baturay, "An Overview of the World of MOOCs," *Procedia Soc. Behav. Sci.*, vol. 174, pp. 427–433, Feb. 2015, doi: 10.1016/J.SBSPRO.2015.01.685.
- [12] J. Santilario-Berthilier, A. Calvo-Morata, I. Martinez-Ortiz, M. Spaniol, and B. Fernandez-Manjon, "SIMVA: Serious Games Learning Analytics Based on

- Standards and Open Code,” *ceur-ws.org*, 2025, Accessed: Jan. 30, 2026. [Online]. Available: https://ceur-ws.org/Vol-3995/GBLA25_paper1.pdf
- [13] C. Alonso-Fernández, I. J. Pérez-Colado, A. Calvo-Morata, M. Freire, I. M. Ortiz, and B. F. Manjón, “Applications of Simva to Simplify Serious Games Validation and Deployment,” *Revista Iberoamericana de Tecnologías del Aprendizaje*, vol. 15, no. 3, pp. 161–170, Aug. 2020, doi: 10.1109/RITA.2020.3008117.
- [14] Á. Serrano-Laguna, I. Martínez-Ortiz, J. Haag, D. Regan, A. Johnson, and B. Fernández-Manjón, “Applying standards to systematize learning analytics in serious games,” *Comput. Stand. Interfaces*, vol. 50, pp. 116–123, Feb. 2017, doi: 10.1016/J.CSI.2016.09.014.
- [15] “e-ucm/xasu: Xasu - xAPI Analytics Submitter / A very simple xAPI tracker with cmi5 support.” Accessed: Nov. 20, 2023. [Online]. Available: <https://github.com/e-ucm/xasu>
- [16] “GitHub - e-ucm/js-tracker: JavaScript xAPI TrackerAsset Implementation.” Accessed: Jan. 27, 2026. [Online]. Available: <https://github.com/e-ucm/js-tracker>
- [17] “GitHub - adlnet/ADL_LRS: ADL’s Open Source Learning Record Store (LRS) is used to store learning data collected with the Experience API.” Accessed: Feb. 05, 2026. [Online]. Available: https://github.com/adlnet/ADL_LRS
- [18] “Veracity Learning Record Store (LRS).” Accessed: Feb. 05, 2026. [Online]. Available: <https://lrs.io/home>
- [19] “TRAX LRS• The Progressive LRS.” Accessed: Nov. 20, 2023. [Online]. Available: <https://traxlrs.com/>
- [20] “GitHub - e-ucm/LimeSurveyXAPITracker: LimeSurvey xAPI Tracker.” Accessed: Jan. 27, 2026. [Online]. Available: <https://github.com/e-ucm/LimeSurveyXAPITracker>
- [21] “xAPI SCORM Application Profile.” Accessed: Jan. 27, 2026. [Online]. Available: <https://tools.xapi.ly/profiles/#/profile/SCORM%20Profile.jsonld>
- [22] “e-ucm/t-mon: T-Mon: Monitor of traces in xAPI-SG in Python.” Accessed: Nov. 20, 2023. [Online]. Available: <https://github.com/e-ucm/t-mon>