xAPI SoTA

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Learning Innovation

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1. Introduction

During the summer of 2015, the Learnovate Centre completed its first project on xAPI. This project was based on feedback from our industry partners that there is an emerging requirement to track disparate learning experiences that take place across the board, through both online and offline experiences. The Learnovate team explored what organisations need in order to enable them to make informed decisions on if, why, and how they should consider xAPI. One of the main takeaways was that the ability to aggregate and infer meaning from all the data collected is key. In this initial project, we also designed a pedagogically meaningful use case and a technical architecture. The team implemented and tested the software.

Learnovate held a workshop for their industry partners in May 2016 and it became clear that many of them have similar questions and challenges with regards to xAPI. The industry partners raised the concern that there is a lack of best practice, especially with regard to how to process the data generated and how to turn it into meaningful data. Partners also appear to remain unclear on the question if and how it can be useful for their organisation, what it takes to implement and use xAPI effectively and how to deal with data privacy.

Because these are all valid questions and concerns, the Learnovate Centre has decided to conduct a follow-up project to identify the current state of the art through analysis of current studies on xAPI, answering questions, such as:

- When to consider xAPI?
- What is the recommended design process when implementing xAPI?

In addition to the SoTA, we have analysed current implementations through analysis of **case studies** (organisations that implemented xAPI, the process they used, things that went well, challenges they ran into, etcetera).

2. Current research: The State of the Art

xAPI was launched in April 2012. Since then, there have been no significant updates to its specification yet it is increasingly being adopted (Berg et al., 2016). The xAPI specification is used to collect learners' digital traces (their learning experiences). Most xAPI data is communicated through statements. A statement is represented in a JSON format and includes, at a minimum, the actor, or user who is being tracked, the verb, or action they are taking, and the object. In other words, the xAPI statements take the form actor-verb-object to store an experience (Berg et al., 2016). According to Berg et al., (2016), "a bandwagon of xAPI showcases and systems is starting to roll in Europe as an increasing number of educational institutions harvest structured and consistent data" (p 544). The authors suggest that there are three innovative aspects that serve as a motivator for xAPI implementation; that is, xAPI is 1) learner activity-centered, 2) system independent, and 3) straightforward to implement from a technical perspective. The authors also state that xAPI has taken a leading role in comparison to other standards such as Sharable Content Object Reference Model (SCORM), Contextualised Attention Metadata (CAM), and IMS Caliper because it provides a

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technical solution to store the activity events in Learning Record Stores (LRSs). In addition, it is relatively easy to get started with collecting xAPI events which is due to xAPI's usability; institutions can define their own statements. The ECO project report (2016) adds that xAPI is used quite frequently in the learning analytics (LA) domain due to its versatility.

2.1 When to consider xAPI: Learning analytics (LA)

When considering xAPI, LA to support learning and performance are most likely the goal while xAPI is the tool to achieve that goal. This section will explore xAPI from this perspective. In general, there can be various reasons to consider to start using LA in an organisation in general. First of all, there is no universally agreed definition of LA. One example of a definition is "the measurement, collection, analysis, and reporting of data about learners and their contexts, for purposes of understanding and optimising learning and the environments in which it occurs" (Siemens, 2011). LA can generally be used to:

- Predict, for example to identify 'at risk' learners in terms of drop out or performance failure.
- Personalise and adapt, for example to provide learners with tailored learning pathways or assessment materials.
- Intervene, for example providing stakeholders (e.g. teachers, managers, organisations) with information to intervene to support learners.
- Visualise information, for example in the form of so-called learning dashboards which provide overview learning data through visualisation tools (Wikipedia).

Bakharia et al., (2016) explain that the reason why LA have evolved as a field is to improve learning processes and outcomes. However, "the learning process is complex and influenced by a wide variety of contextual and personal factors" (p 1). In addition, as also discussed by Cooper (2014), learners usually don't learn on only one platform. For example, de Laat & Schreurs, (2013) describe how LA "can be applied to harvest and analyse information about learner activities with a focus on learning behaviour in the frame of formal learning activities, such as completing assignments and taking exams, and more informal settings, such as posts on discussion forums and online social interactions" (p 1425). This is an example of how learning data is usually generated from numerous platforms. Furthermore, establishing a combined data set is a known challenge in this context (Bakharia, 2016).

This is where the standards specifications for LA come in. The LACE project (see an overview here) explains that there are three types of fora conducting standardisations activities and each has their own standard; that is

1) industry or stakeholder consortia using Experience API, Caliper, and HR Open Standards
2) international or regional standardisation organisations; The European Committee for Strandardisation (CEN TC353)
3) international standardisation bodies; International Organisation for Standardisation (ISO) and The Institute for Electrical and Electronics Engineers (IEEE).

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In addition, there may be more informal, and often open-access, collaborations working on pre-standardisation tasks, such as the Open Learning Analytics (OLA) platform, the European Committee for Standardization (CEN WSLT).

For the context of Learnovate members, xAPI and Caliper are the most common standards. They will be compared in section 2.3 in the context of interoperability.

2.2 Recommended Design Process

In order to use learning analytics effectively, they need to be considered at the very beginning of the design process when implementing xAPI.

The Tin Can API website explains two design processes. First, **event-driven experience design**, which refers to identifying the experiences within a learning or performance solution as well as determining what useful data could be collected about that experience. Second, the website mentions **analytics design**, which is needed to be able to interpret the quite complex analytics reports that a Tin Can-powered analytics tool will deliver.

The first step in LA design is exploring the questions that are important to 'the business', for example "Does encouraging social learning amongst the sales team drive more sales?" The next step is developing a hypothesis. In other words, decide what you think the answer to the question is and plan out what data you can capture to either prove or reject your hypothesis. Next, you will need to design your experiment and you will need to determine how to analyse the data to answer your question. Finally, you need to implement the experience and evaluate it.

HT2 Labs (through personal communication with Ben Betts) recommends helping clients discover their needs before they get started with designing for xAPI, which might sound obvious but is a step that is easily overlooked. In HT2 Labs' experience all clients are different and have different needs and approaches. Some clients start from a system perspective (for example, using xAPI in their LMS), which is a more 'facile' level of implementation. Some clients have a particular use case in a specific learning and/or performance context. Often times, the need for xAPI is triggered by an operational need; a tangible problem that needs to be solved. Some also have a real data strategy and design for the future as well (for example, they envisage a pipeline based on current and future systems; that is a learning architecture perspective). Some organisations even reset their whole strategy before they start implementing xAPI. In summary, it is critical to analyse the problem and map it out before the design process kicks off.

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2.3 Implementation

There are many options for how you might go about introducing xAPI into your organisation. At the most fundamental you could decide to implement the xAPI standard yourself and roll out your own LRS.

The next option would be to take an off the shelf LRS and integrate that with your existing learning management system. This is the sense of 'implementation' we will address in this section.

Berking (2015) had some very valid assertions in relation to best practices for implementing and /or integrating xAPI. He observed that currently, most LMSs are focused on offering the option of performing SCORM-like functionality using the xAPI instead of SCORM, rather than leveraging the unique features of the xAPI. Berking (2015, p 11) states that:

> "In order to achieve the latter, vendors will need to profoundly rethink their LMS product model. There are three main areas of LRS capabilities that LMS vendors need to consider in this new product model.
>
> One relates to the LRS's ability to track learning experiences within content other than standard eLearning, such as mobile "learnlets," simulations, and games. It also needs to track it whether or not it is launched from the parent LMS.
>
> Secondly, the LMS needs to leverage the fact that an added LRS can track different kinds of data than is possible using SCORM or proprietary LMS tracking capabilities. This includes various kinds, such as:
>
> - Attempts, levels achieved, and other milestones rather than simply complete/incomplete or test scores
> - Complex learner behaviours that are not part of formal assessments
> - Data from learning activities conducted by groups of learners
>
> Third, the LMS needs to account for the fact that an LRS can track, analyse, and report on a wide range of administrative data other than learner performance, regarding such things as how content is being used (including content outside of the LMS), apparent gaps in topics and areas of knowledge, trends in learner performance, etc.
>
> These three dimensions are particularly apparent with regard to informal learning that does not necessarily originate from the LMS.

We could take it a step further and suggest that any SOTA xAPI implementation needs to also focus on the opportunities for interoperability and data sharing afforded by the LRSs and the concept of federation of LRS's that is central to the xAPI specification.

Keeping an LRS as a standalone complement to an existing LMS rather than integrating it inside an LMS should preserve a lot of what is most effective about the LRS concept: the ability to push and pull data to and from other LRS's and systems.

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Coding examples for xAPI and IMS Caliper

Both xAPI and IMS Caliper offer facilities to collect learning events from different platforms. The xAPI allows for statements to be sent to the LRS from phone apps etc. Caliper Sensors are pieces of code that can be used by programmers to include Caliper functionality in their learning applications.

In coding terms the two are similar. Below is an example of sending an xAPI statement to an LRS:

```
tincan.sendStatement(
    {
        actor: {
            mbox: "mailto:your.email.address@example.com"
        },
        verb: {
            id: "http://adlnet.gov/expapi/verbs/attempted"
        },
        target: {
            id: "http://tincanapi.com/activities/sending-my-first-statement"
        }
    },
    function (err, result) {
        // Handle any errors here. This code just outputs the result to
        // the page.
        document.write("<pre>");
        document.write(JSON.stringify(err, null, 4));
        document.write("</pre>");
        document.write("<pre>");
        document.write(JSON.stringify(result, null, 4));
        document.write("</pre>");
    }
);
!
```

Figure 1: xAPI Send Statement Code

In addition, below is code to achieve a similar task for Caliper:

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```
var#sensor#=#Caliper.Sensor;###
###
#//#Note#that#you#will#have#to#create#a#new#request#bin###
#//#by#navigating#to#http://requestb.in/###
#//#and#replace#the#"path"#setting#below#with#the#path####
#//#to#your#request#bin###
#sensor.initialize({###
###host:#'requestbKinK1h04eq0e08pc.runscope.net',###
###path:#'/155a98q1',#//#REPLACE#WITH#YOUR#REQUEST#BIN#PATH###
###withCredentials:#false###
#});###
###
#//#Wrapper#around#Caliper#Sensor's#send()###
#var#send#=#function(event)#{###
###
###//#Perform#any#preKprocessing,#etc.###
###
###//#Send#Events#using#Caliper#Sensor###
###sensor.send(event);###
#};###
```

!

Figure 2: Caliper Sensor Send Code

These code examples are just to illustrate the data-gathering aspect of the implementations. They don't refer to the application of the analytics to the acquired data or to the work that may be necessary when sharing such data.

Depending on the chosen implementation paradigm, for example if you are integrating an LRS with an existing LMS, there may be a need to develop some middleware solutions for data exchange and conversion as part of the conversation.

Downes, Shahrazad and Smith (2015) suggest that the transfer of xAPI data from one LRS to another does not always work smoothly. This highlights the importance of the consistent application of the API recipes and the validation of statements according to the recipe.

Another related issue is the lack of shared conventions and best practice examples for xAPI statements that are authoritatively endorsed by educational communities. This raises a level of uncertainty for adopters over their own xAPI definitions and approaches.

The recently published Edinburgh Statement for Learning Analytics Interoperability advocates open dialogue between vendors, practitioners and organisations and the establishment of common, shared and accessible spaces to facilitate this dialogue. Project ECO learning (2017) is an example of a project that aims to achieve this. ECO-MOOC providers submit xAPI statements to a cloud-based xAPI proxy. The proxy component takes care of managing a copy of the xAPI statements. Furthermore, it forwards the statements to a BigData LRS, a customized data store optimized for making scalable and performant queries. These components were introduced to enable queries by the dashboard component that cannot be executed live on the LRS due to long reaction times. Introducing an xAPI proxy can be beneficial for error-handling and caching. In the event that the LRS is down or cannot handle the load, the proxy can publish statements at a later time.

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It is also worth noting that some LRS's such as Watershed LRS store xAPI statements in a relational database in addition to storing them in their native LRS form (non-SQL database). This takes the burden off the APIs and middleware to make this translation. External databases can then directly communicate with the LRS database and more importantly integrators of external analytics systems should find it much easier and faster to produce visualisations of the data.

Interoperability challenges and how to tackle them

When an xAPI implementation requires integration of several platforms, there are several challenges that need to be tackled.

Firstly, the various systems that learners use often use different underlying data structures. In addition, the data structures in these systems are not always designed for analytics but rather for teacher and learning use cases (e.g. accessing content or participation in discussion forums) in a technically scalable and maintainable way. As a consequence, "practical learning analytics requires that data moves from operational to analytical systems and be put to a different use than originally intended" (Cooper (2014), p 1). In other words, first, data has to be re-interpreted and second, common meaning to the data needs to be established. Comparing xAPI and Caliper in terms of interoperability can help to shed some light on this matter.

Historically, data structures in LMSs are not likely to have been designed with analytics in mind. As a result, when an organisation decides they want to undertake statistical processing or data mining, data has to be re-interpreted, reformatted, or restructured. This situation is further amplified by the necessity of combining data from various sources, or the possible requirement for cloud-based data mining engines to apply useful statistical and predictive models.

The most difficult challenges with achieving interoperability are typically found in establishing common meanings to data. The most obvious differences between xAPI and Caliper are the openness of the underlying platforms.

xAPI defines the statement pattern and how statements are stored and retrieved. It does not specify what verbs to use in those statements. While this allows the implementer a great degree of flexibility, it has proven to be a double-edged sword in the way that this flexibility can also impede clarity in relation to what a learner has achieved when trying to compare results across systems.

For useful interoperability in xAPI the various communities need to get together to reach consensus definitions and add mechanisms to support interoperability beyond the specification itself. A lack of conformance and certification has to date presented a barrier to the adoption of xAPI.

IMS Caliper provides specifications for interoperability including Learning Tools Interoperability (LTI), Learning Information Services (LIS), Question and Test Interoperability (QTI) but should be regarded as a closed platform, not only in development terms but in terms of licensing as well.

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That said, it is a lot more complete in what it defines compared to xAPI. (Hoel, Griffiths, & Chen, 2016) assert that this is for good reason; the nature of questions, tests, and the results of them is sufficiently complicated that more ideas must be defined before a specification becomes useful.

The overall effect though is that it is less flexible than xAPI and that there is less opportunity to extend in the event that desired functionality is not available. In contrast this restrictiveness affords greater clarity about how QTI works.

Thus, while the scores that learners might get on sections of an assessment, or even the order in which they attempt questions could be sensibly captured with xAPI, possibly using terms defined in QTI, a more detailed analysis of interactions is likely to require access to data about the question item structure that would best be expressed in the purpose-build form of IMS QTI.

In addition to interoperability, another important topic to consider when implementing xAPI is privacy.

2.4 Data analysis & visualisation

In order to gather the data you need to get the insights you want, you need to start asking the right questions. Delano et al., (2013) warn that learning analytics should encompass a certain amount of detail in order to be meaningful. In other words, it is important to focus on learner-centric data instead of site-centric data.

Two examples are:

Question	Site-centric or Learner-centric analytics?
How many users engage with a site or tool?	Site-centric analytics
How a single user engages with different sites or tools?	Learner-centric analytics

Last but not least, one of the major risks is that the tracking will be technology-led. It is critical to understand your users and their focus or goal rather than relentlessly tracking as many activities as possible (Downes, et al., 2013).

In addition, (Fox, 2015) argues that nearly all data and analysis used will be correlational by nature. Correlational analyses can be good for prediction, however, they are not always capable of identifying how to change or influence learning or performance. Also, of course correlation does not imply causation. (Brownlie, 2014), provides an example in which an organisation attempts to correlate xAPI parameters with actual business results. This analysis may produce findings such as “Sales people with the highest revenue in Q2 took training classes X, Y and Z”. There could be many reasons why sales people with the highest revenue in Q2 took these training classes that have nothing to do with the effectiveness of the training. Perhaps all sales people took the same training classes as part of mandatory training. If that is the case, the worst performing sales people also took training classes X, Y and Z.

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"It is also important to realise that a certain level of statistical experience is required to initially design for and make sense of learning analytics and there is great potential for misreading the available data" (Brownlie, 2014). Ferguson et al., (2013) argue that, as learning analytics emerge from the wide fields of analytics and data mining, its researchers need to collaborate with learning specialists. That way, there is a potential for a two-way process, with learning analytics forming the basis for good learning design and effective pedagogy.

Learning Designers are uncertain of how to design for the data that is being collected. Data Scientists have insufficient knowledge on how to evaluate learning impact. They need to collaborate and learn from each other in order to be able to implement an effective xAPI solution.

Another sub challenge with regard to design for and interpret data is the focus. (Brownlie, 2014) carefully compares the xAPI structure with SCORM and alternative tracking methods, such as Open Badges, web page logs, Google analytics, HTTP cookies and mouse and eye tracking. From this comparative analysis, two fundamental challenges arise when applying the general tracking methods to learning experiences for individual users. First, in order to be able to attach particular meaning or context to the tracked variables, significant retrospective analysis is required. Second, all the tracking methods have been developed to evaluate sites, not learner-centric experiences. xAPI is the preferred method to track and analyse learning experiences. However, even when using xAPI instead of general tracking methods, the risk is still that the tracking of the learning experiences will be site-centric and technology led. It is critical to understand your users and their focus or goal rather than relentlessly tracking as many activities as possible (Downes, et al., 2013).

2.5 Privacy

Privacy is a policy decision that needs to be made in light of the information-sharing that you intend to implement and the analytics you wish to draw; it is not just a case of encrypting everything.

First, you have to decide what you want to share, with who, in what detail and for what purpose. The chosen purpose constrains you in what level of privacy you are going to achieve. Different levels of anonymization may or may not work for said purpose.

For example, if you want to provide analytics at only a group level you could take steps to eliminate all personal identification from the data. But if you want to be able to drill down then you will not be able to be as stringent with anonymizations because you will eventually need to be able to identify individuals.

A lot also depends on what it is that you want to analyse. If you want to evaluate an individual and their progress, then you are very limited in what you can anonymise. If you want to evaluate the learning material or the instructor, then you have a much different proposition.

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Data stored in an LRS (or LMS) can be divided into two distinct domains: Data concerning activities and data that can be used to establish the identity of the learner.

The designers of xAPI have chosen a safe route (Del Blanco et al., 2013) through the privacy issue by not providing any specific support for learner profiles. The xAPI LRS is decoupled and is a good choice for accessing and sharing data, but that openness exposes the data to risk. It is left as an exercise for the adopter to (a) decide if they will store profile data and (b) decide how to take responsibility for protecting any stored identities.

In some circumstances the omission of learner profiles in the xAPI LRS may prove to be an advantage. Sclater & Bailey report on an Apereo/Jisc workshop in Paris, stating that "...almost immediately at the architecture workshop issues relating to privacy were raised. These were of such concern to the Germans present that they believed their learners would not be prepared to use a learning analytics system unless the data was gathered anonymously." (Sclater & Bailey, 2015). They go on to say that the availability of a Consent Service would have to be considered as a critical part of any LA system architecture.

3. Conclusion

This report is a response to questions raised by our industry partners on best practice in the context of xAPI, for example how to process the data generated through xAPI and how to turn it into meaningful data. Partners also appear to remain unclear if and how xAPI can be useful for their organisation, what it takes to implement and use xAPI effectively and how to deal with data privacy. Through analysis of current studies on xAPI, this State of the Art report aims to answer the following questions:

- When to consider xAPI?
- What is the recommended design process when implementing xAPI?

This section summarises the findings as outlined in this SoTA report.

3.1 When to consider xAPI

When considering xAPI, it is likely that LA are the starting point. LA can be applied to track and analyse information about all kinds of learner activities, ideally with the focus on learner behaviour in both formal and informal settings. This suggests that learning data is ideally generated from numerous platforms which also brings the challenge of establishing a combined data set to the surface. This is where the standards specifications (in the context of this SoTA that is xAPI).

3.2 What is the recommended design process when implementing xAPI

From the SoTA analysis, the following recommended design process can be identified:

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Problem analysis phase

In general, the first step in LA design is a problem analysis phase; that is exploring what problems need to be solved or what questions need to be answered.

How 'deep' you can dive also depends on the higher level approach that you are taking when planning to design for xAPI. You could take a:

1. System approach; using xAPI in an LMS
2. Use case approach; particular learning and/or performance need
3. Data strategy approach (for example, envisaging a pipeline based on current and future systems; that is a learning architecture perspective).

High level design approach

There are two recommended xAPI design processes:

1. Event-driven experience design - identifying the experiences within a learning or performance solution as well as determining what useful data could be collected about that experience.
2. Analytics design, which is needed to be able to interpret the quite complex analytics reports that a Tin Can-powered analytics tool will deliver.

Next, you will need to design an experiment and you will need to determine how to analyse the data to answer your question. Finally, you need to implement the experience and evaluate it.

Implementation

With regard to implementing xAPI, there are various options to consider. What the best option is really depends on your context. One option is to implement the xAPI standard yourself and roll out your own LRS. Another option is to take an off the shelf LRS and integrate that with your existing learning management system.

Then, there are a couple of things to consider:

- Does the LRS needs to be able to track learning experiences within content other than standard eLearning, such as mobile "learnlets," simulations, and games.
- Does it need to track it whether or not it is launched from the parent LMS?
- Does the LMS need to leverage the fact that an added LRS can track different kinds of data than is possible using SCORM or proprietary LMS tracking capabilities?
- Does the LMS need to account for the fact that an LRS can track, analyse, and report on a wide range of administrative data other than learner performance, regarding such things as how content is being used (including content outside of the LMS), apparent gaps in topics and areas of knowledge, trends in learner performance, etc.

Some of the main challenges are:

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- The various systems that learners use often use different underlying data structures. The data structures in these systems are not always designed for analytics. As a consequence, data has to be re-interpreted and second, common meaning to the data needs to be established.
- When you want to undertake statistical processing or data mining, data has to be re-interpreted, reformatted, or restructured.
- xAPI defines the statement pattern and how statements are stored and retrieved. It does not specify what verbs to use in those statements. While this allows the implementer a great degree of flexibility, it can also hinder clarity in the overall data when statements are not well designed (e.g., aligned).

Data Analysis and visualisation

The main challenges with regard to data analysis are as follows:

- It is important to focus on learner-centric data instead of site-centric data. Make sure the data is use-centric instead of technology–led (e.g., don't just track as much data as possible just because you can).
- Keep in mind that nearly all data and analysis used will be correlational by nature. Correlational analyses can be good for prediction, however, they are not always capable of identifying how to change or influence learning or performance. Also, of course correlation does not imply causation.
- You need a certain level of statistical experience to initially design for and make sense of learning analytics
- Experts from the analytics and data mining fields need to collaborate with learning specialists. That way, there is a potential for a two-way process, with learning analytics forming the basis for good learning design and effective pedagogy.

Privacy

Privacy is a critical design element; it is something to consider from the start of the design process. It should not be something to just decide on later on. You need to decide what you want to share, with who, in what detail and for what purpose. The chosen purpose constrains you in what level of privacy you are going to achieve. Different levels of anonymization may or may not work for said purpose.

Data stored in an LRS (or LMS) can be divided into two distinct domains: Data concerning activities and data that can be used to establish the identity of the learner.

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