LACE

Learning Analytics Community Exchange

Comparing xAPI and Caliper

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Abstract: There are two principal specifications for learning analytics interoperability: Caliper, from IMS, and xAPI, from ADL. Around these two specifications are emerging ecosystems of applications and related specifications. The two specifications are introduced, and their structure and main features outlined. The differences in their approach to development are described, with Caliper being developed by a closed consortium, and xAPI in an open process. Efforts to bring the specifications closer together are outlined, and the some reflections offered on the strategic implications of the differences between the specifications.

Contents

Executive Summary

This paper builds on the LACE public deliverable D7.4 Learning Analytics Interoperability: Requirements, Specifications and Adoption, published in January 2016. It extracts from that deliverable the material which is most relevant to the xAPI and Caliper specifications, in order to provide a more concise discussion which can be consulted by those who are considering adopting one of the specifications, or making use of applications that support them.

In many respects xAPI and Caliper perform similar functions, making use of similar concepts. They are, however, quite different in their approaches to development and governance. Caliper has been created through a closed process in a membership organisation, while xAPI has emerged from an open process where all interested parties are welcome to contribute. The intellectual property of Caliper is retained by IMS, while, in contrast, xAPI is made freely available to all on an Apache 2 license. This difference in approach is reflected in a different emphasis in the approach to the fit between the specifications and their user groups. Caliper focuses in the first instance on use cases gathered from IMS member organisations, while making provision for extensions. xAPI delegates to communities of practice much of the responsibility for defining the vocabularies for use with the specification, while also taking a role in ensuring core functionality. This has substantial implications for adopters, who may need to decide if the flexibility offered by xAPI is valuable to them, or if they prefer to work with the predefined functionality which is offered by the large LMS providers who seem likely to be prominent users of Caliper.

Some efforts have recently been made towards harmonisation of the two specifications, but it is not clear yet to what extent this will be possible. It should, in any event, be an attainable goal to enable the two specifications to interoperate with each other in the same institutional implementation, and we suggest that all interested parties demand that this functionality is indeed made available.

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Introduction

The interoperability of learning analytics (LA) systems has been a key of the learning analytics community at least since the proposal for 'Open Learning Analytics: an integrated & modularized platform' (Siemens et al. 2011). Five years later, we now have two alternative major initiatives that have developed specifications for the management of learner data, xAPI and Caliper, and around them are developing two competing infrastructures for carrying out learning analytics. In order to make sense of this situation, learning technologists and institutional managers need to understand what these specifications do, and the ways in which they differ. These distinctions are not only technical. They also, and perhaps principally, concern the differing models of ownership, governance and community engagement adopted by the two specifications, and the implications that these will have for the types of services which the specifications will support, and the flexibility with which they can be used.

This paper seeks to provide a straightforward description of the two specifications that can help the newcomer to this field to reach an informed judgement on the current state of play of learning analytics specifications. In doing this we build on the LACE public deliverable D7.4 Learning Analytics Interoperability: Requirements, Specifications and Adoption (Griffiths & Hoel 2016), selecting and updating the material from that report which is most relevant to the xAPI and Caliper specifications.

Some relevant prior specifications

Learning Analytics (LA) has not suddenly appeared as an entirely new approach. There has been a long tradition of work that leverages student data, reaching back to the early days of adaptive learning (e.g. Carbonell 1970), and the Educational Data Mining field that emerged in the 1990s (see Romero & Ventura 2007). From these varied fields of work, some specifications emerged which were relevant to the emerging needs of learning analytics. The LACE publications *Learning Analytics Interoperability – The Big Picture in Brief* (Cooper 2014a) and *Specifications and Standards - Quick Reference Guide* (Cooper 2014b) gave an overview of the standards that could play a role in promoting LA interoperability. Some of the standards are related to activity information, while other standards are related to processes of analytics and visualization following the description of activity stream. In the context of this review paper it is sufficient to briefly highlight three relevant specifications, Activity Stream, PMML, and SCORM.

Activity Streams

The proposal to create a specification for activity streams emerged around 2009 when it became clear that there was no interoperable format for exchanging and syndicating information about activities from social media. The work was undertaken by a group from IBM, Google, Microsoft, MySpace, Facebook, VMware and others, which published its first version in 2011. The first sentence of the Introduction to version 1.0 reads:

> In its simplest form, an activity consists of an actor, a verb, an object, and a target. It tells the story of a person performing an action on or with an object -- "Geraldine posted a photo to her album" or "John shared a video". In most cases these components will be explicit, but they may also be implied. (Activity Streams Working Group 2011)

The specification was adopted by many large players in the social media scene (e.g., Facebook and MySpace). In 2014 the specification was handed over to W3C Social Web Working Group, and version 2.0 is published as a working draft (W3C Soccial Web Working Group 2015). Experience API and IMS Caliper both build on the Activity Streams work, and in a LACE guest blog post Kitto (2015) suggests that the Activity Streams specification could be used to unify the two specifications in spite of fragmentation due to different market strategies of the players in learning analytics.

Predictive Model Markup Language (PMML)

Interoperability of models and methods is the aim of PMML, the Predictive Model Markup Language, a mature XML-based specification from the Data Mining Group[1]. Although its emphasis is on predictive methods such as decision trees and logistic regression, it can also be used to convey the results of more common statistical tests. PMML allows for data transformations and other pre-processing steps, algorithm selection, and fitted parameters, etc., to be exchanged. There are several independent implementations of PMML, however, the standard has not been widely used for learning analytics. The Interoperability work package of LACE has, however, concluded that no evidence is found that would prove PMML inadequate for learning analytics. Indeed, the Open Academic Analytics Initiative (OAAI) is built on PMML, and the OAAI has been adopted by Jisc Open LA framework as part of its open architecture. PMML is also part of Apereo's Learning Analytics Processor[2].

From SCORM to xAPI

Advanced Distributed Learning (ADL), a division of US Department of Defence, has been responsible for both the highly successful SCORM specification, and xAPI, which in some respects replaces the earlier specification (note that *xAPI* and *Tin Can API* are synonymous for historical reasons[3]). It is worth briefly examining this background.

SCORM, the Sharable Content Object Reference Model, was first released in 2001, with a major revision in 2004. It was based on work by the Aviation Industry Computer-Based Training Committee (AICC) going back 20 years specifying how the desktop, later the web browser, could communicate with content. SCORM enabled interoperability between systems (LMS and training content) to become a reality. It supported one pedagogical scenario, and was based on the infrastructure of the time (desktop computer, web browser, institutional servers). It was also assertively marketed as the gold standard for elearning, which made it hard for educators to buy into the benefits of technology standards for learning. There is no reason why SCORM and LA specifications cannot work together, and there is an xAPI SCORM profile, which provides guidelines for representing SCORM data and events as xAPI statements (ADLnet n.d.).

xAPI

The introduction of mobile devices, increased use of simulations and gaming in military training, and the fact that large groups of students were no longer satisfied with the use of an LMS for other than obligatory tasks made it clear to ADL that SCORM needed updating. The US Government commissioned a study called Project Tin Can that resulted in the data transport and storage

[1] http://www.dmg.org/v4-1/Interoperability.html
[2] https://confluence.sakaiproject.org/display/LAI/Apereo+Learning+Analytics+Processor
[3] See https://tincanapi.com/tin-can-xapi/ for an explanation of this double naming.

mechanism called Experience API (xAPI), the first component in ADL's Training & Learning Architecture. xAPI, in contrast to SCORM, is able to track any activity, not only completion data and scores. After 10 years with SCORM xAPI was released in 2013 as the first component of ADL's Training and Learning Architecture, heralded by some as the Future of SCORM (Werkenthin 2014). xAPI does not replace everything that SCORM does; it is not designed for scheduling, there is no sequencing, no user management feature, etc. (Werkenthin 2015). It is proposed as only the first building block in a system that will include Learner Profiles, Content Brokering, and Competency Networks (Jonathan Poltrack 2014). In 2016 the Data Interoperability Standards Consortium (DISC) took on ownership of xAPI, with the mission of acting as custodians of the specifications open source status.

According to ADL "The Experience API is a service that allows for statements of experience to be delivered to and stored securely in a Learning Record Store (LRS)" (ADL 2013). The basic structure that makes this possible is as follows:

- People learn from interactions with other people, content, and beyond. These actions can happen anywhere and signal an event where learning could occur. All of these can be recorded with the Tin Can API.
- When an activity needs to be recorded, the application sends secure statements in the form of "Noun, verb, object" or "I did this" to a Learning Record Store (LRS.)
- Learning Record Stores record all of the statements made. An LRS can share these statements with other LRSs. An LRS can exist on its own, or inside an LMS. (Tin Can API n.d.)

The xAPI specification is published as a living document[4]. We now provide an overview of the specification for readers who do not have the time or inclination to read the technical documentation (though we should add that this documentation is not too intimidating). The overview is based on the current version 1.0.2, and draws extensively on that text. Direct quotations are not indicated in order to maximise legibility, and readers are referred to the specification itself for the authoritative text.

The xAPI model of a learning experience

The fundamental concept in xAPI is the statement, a simple construct that tracks an aspect of a learning experience. A *Statement* consists of an `<actor (learner)>`, a `<verb>`, an `<object>`, with a `<result>`, in a `<context>`. There is no constraint on what these objects should be. We now briefly introduce these elements in turn.

Actor: An *Actor* is the identity or persona of an individual or group that can be tracked using Statements when they perform an action within an *Activity*.

Object: An object is the "this" part of the Statement, i.e. "I did this". Typically the *Object* is an *Activity* (e.g. "Jeff wrote an essay about hiking"). The Object can also be an Agent (e.g. "Nellie interviewed Jeff.") or a Sub-Statement (e.g. "Nellie commented on 'Jeff wrote an essay about hiking.').

[4] https://github.com/adlnet/xAPI-Spec/blob/master/xAPI.md

Activity: An *Activity* is a type of *Object* in a *Statement*. The concept of *Activity* in xAPI is a little different from everyday language. *Activity* refers to something that an *Actor* interacted with. It could be a unit of instruction, an experience, or a performance that can be tracked in combination with a *Verb* that defines the action carried out. *Activity* can even refer to tangible objects such as a chair (real or virtual). In the statement "Anna tried a cake recipe", the recipe constitutes the Activity in terms of the xAPI statement. Other examples of activities include a book, an e-learning course, a hike or a meeting.

Verb: Describes the action performed during the learning experience. The xAPI does not specify any particular *Verbs*. Instead, it defines how to create Verbs so that communities of practice can establish *Verbs* meaningful to their members and make them available for use by anyone.

Result: The *Activity* carried out by an *Actor* may lead to a measured outcome related to the Statement in which it is included (though this does not have to be the case). The kinds of results foreseen in xAPI are scores, success, completion, response, and duration of the activity. However it is possible to define more types of result.

Context: The *Context* can store additional information about an *Activity* or experience, but this is optional. For example, the *Context* could include the teacher or instructor, whether the experience happened as part of a team *Activity*, or how an experience fits into some broader activity.

Attachment: In some cases it is important to store a file that provides evidence of a learning experience. For example, this could be a record of communication, an essay, a video, or a certificate that was granted as a result of an experience.

The elements described above provide an indication of the way that xAPI models learning experiences. However, this is not sufficient to actually work with learning experiences. The specification defines a number of further elements. We now mention two of these that particularly help in understanding how the specification works.

Learning Record Store (LRS): The *Learning Record Store* is a system that stores learning information, and xAPI is dependent on the presence of an LRS if it is to function. In the past most learning records were stored on Learning Management Systems (LMS). But the LMS is no longer the unquestioned centre of every technology enhanced learning environment. The use of an LRS element makes it clear that it is not necessary to work with a full LMS in order to implement xAPI. A reference implementation of he Learning Record Store is available on the ADL Github site[5].

Activity Provider (AP): The Activity Provider is the software that communicates with the Learning Record Store to record information about a learning experience. The *Activity Provider* may not actually support the learning experience itself, for example the activity “Nellie interviewed Jeff”, the interview itself could be carried out with pencil and paper.

Other essential information for working with statements is provided by the *Timestamp* (indicating when the experience occurred), *Authentication* (to verify the identity of a users and systems), and *Authority* (which indicates who or what has asserted that a *Statement* is true).

[5] http://adlnet.github.io/

Flexibility and interoperability: squaring the circle

Even though SCORM was marketed as the LMS standard, it was primarily its tracking feature (adopted from the AICC CMI specification) that justified the work required to build SCORM into an LMS. However, SCORM could only track a very limited and fixed set of activities. In response to this limitation xAPI is much more versatile in its tracking. The specification offers a framework for the description of learning experiences, enabling users to define their own vocabularies, and to extend Activity Definitions, Context, and Result. This offers many advantages, but also comes with a cost, as Werkenthin points out:

> One of the great things about xAPI is that you can define your own verbs and extensions. This allows you to track everything needed to analyze your learner's experience, but it is another reason that xAPI is not the "new SCORM." For example, what verbs or extensions indicate "completion" of a course? There's no definition. Sure, you can make your own choice, but interoperability is lost. (Werkenthin 2015)

ADL, too, was aware that this "structured but incredibly open way of dealing with data" is the specification's "greatest strength and weakness" (Bowe 2013). xAPI is based on a language that lets us express everything. However, as we know from our own language experiences it is not enough to have a language, one also need a vocabulary to come up with meaningful statements. A vocabulary implies a community; and this is what we observe in many countries nowadays, communities of interest meet to define vocabularies allowing them to exchange activity data. These vocabulary sets have been referred to as *recipes*, but current practice in ADL is to use the term *profiles*. The specification explains that "Communities of practice (CoPs) will, at some point in time, need to establish new *Verbs* to meet the needs of their constituency. Therefore, it is expected that xAPI communities of practice generate profiles, lists, and repositories that become centered on *Verb* vocabularies". ADL is coordinating the creation of collections of recommended *Verbs* by communities of practice, and this work is likely to continue to be supported by ADL's participation in the recently established Data Interoperability Standards Consortium (DISC). Individual activity providers remain can, nevertheless, make their own choice of *Verb*.

According to the specification a Controlled Vocabulary is

> …a restricted, agreed-on list of words … used for a specific domain of knowledge. The objective of a controlled vocabulary is to ensure consistency in the development and implementation of xAPI statements to avoid ambiguity and ensure the use of consistent language. It is controlled because only terms from the list may be used for the subject area or domain. It is also controlled because, if it used by more than one person, there is control over who adds terms to the list, when, and how to the list. The list could grow, but only under defined policies by a CoP. (ADL 2013)

CoPs are also expected to develop domain profiles, i.e. reusable templates that convey domain-specific or use case requirements, documentation, vocabulary, and sample statement(s) for how to capture specific types of learning experiences using xAPI. An example of an emerging domain profile is the Serious Games xAPI Profile[6] currently being developed by Universidad Complutense de Madrid

[6] The current draft is available at https://docs.google.com/spreadsheets/d/1o1qukRVI_eWpgnarh3n506HbzT1QTxerJ9eIfOfybZk/edit#gid=0

as part of the RAGE project[7]. Similarly the Connected Learning Recipe provides a means to model social media interaction as xAPI statements (Kitto n.d.).

As a result of the flexibility of xAPI there is also a need to add mechanisms to support interoperability beyond the specification itself. Miller (Miller 2014a) explains the importance of the Registry as a solution to this problem. As the specification approached a 1.0 release, it became apparent that switching the identifiers for Verbs and other Statement parts to URIs was going to leave a gap. Out of that recognition came the Registry. The Registry provides a place for users of the Tin Can API to catalogue the various terms they use to construct Statements (Miller 2014b). Thus xAPI is not a stand-alone specification, but rather, as the specification states "the first of many envisioned technologies that will enable a richer architecture of online learning and training. … the Experience API is designed with this larger architectural vision in mind." (ADL 2013)

Towards standardisation

The architectural implications of xAPI, however, expanded its scope beyond the description and transport of activity streams, by introducing the concept of a Learning Record Store. This has generated some controversy in the context of the formal standardisation process. When xAPI was offered for standardisation in IEEE August 2014 "it wasn't the slam dunk [they were] naively hoping it would be" (Silvers 2014b). The proposal was rejected for two reasons: IEEE requested a more modular structure of the specification, and European IEEE members in particular requested a clearer discussion of issues of privacy (Hoel 2014).

However, a strength of the xAPI specification is that it is published with an Apache 2 license. Aaron Silvers comments that

> One might think it odd to license a spec that way, but it makes it possible to allow derivative works -- meaning ADL (vis a vis the US Department of Defense) doesn't need to give permission to IEEE to make a standard from the spec, which makes it possible for it to go into standardization whenever -- a challenge that was really difficult to do with SCORM.
>
> There are no IP issues in the wings with this effort, no dependencies on other organizations IP or prior works. These are all pretty administrative issues but they are the kinds of things that made getting SCORM out of ADL/USDoD nigh impossible... and they're the kinds of things I and others took great care with and deliberated over so as to avoid making choices that turned out to be mistakes later on. (Silvers 2014a)

CMI5

CMI5 is a runtime communication data tracking framework under development by ADL together with The Aviation Industry CBT Committee (AICC). CMI-5 runs on top of xAPI, and seeks to make the openness of the specification tractable for users of common LMS systems. The CMI5 specification defines how the LMS and the content will communicate using the xAPI Learning Record Store (LRS). CMI-5 is a "use case" for xAPI for the LMS ("xAPI with rules"), specifying 10 CMI5 verbs:

- **Session verbs**: launched, initialized, and terminated.
- **Status verbs**: passed, completed, waived, failed, abandoned, and satisfied.

[7] See www.rageproject.eu

The “extra rules” in CMI-5 define “plug-and-play” interoperability between traditional LMS systems and learning content activities.

CMI-5 requires conformance with xAPI, and allows for the flexibility of xAPI to be used in any way which does not conflict with CMI-5. An LMS which is CMI-5 compliant must use the CMI-5 launch mechanism, include required CMI-5 statements in all sessions, define sequence and completion criteria, and provide a user interface to access all data recorded. If successful, CMI-5 will harness the flexibility of xAPI as a way of going beyond the limitations of SCORM, while maintaining a clear and practical approach to standardising information about activities and learning experiences provided on LMS systems. Rustici Software are including CMI-5 support in both their Scorm Engine[8] and Scorm Cloud[9]. The CMI5 specification is open source and the current draft version if available on Github[10]. Development can be followed on Twitter[11]. Poltrack (2016) provides a useful summary of the different roles of CMI5 and of the xAPI Scorm Profile.

IMS Caliper Analytics

The context of the Caliper specification

IMS Global Learning Consortium Inc. is a non-profit, member organization founded in 1999 that strives to enable the adoption and impact of innovative learning technology in education (IMS Global Learning Consortium n.d.). Membership is by annual subscription, which in 2015 varies from $1,500 to $55,000 depending on the size of the institution (IMS Global Learning Consortium 2015a). Members include major software companies and publishers, universities and government agencies[12]. Specification development is carried out in private by groups of members, who also vote on the approval of specifications for publication. Once approval has been given by members, IMS specifications are published on the IMS website.

The response of IMS to the emergence of learning analytics reflects the interests of its members, whether this may be to improve products and maintain market position, or to ensure that the products which educational institutions purchase provide appropriate functionality and offer the benefits of interoperability. An introduction to the specification has been published by Educause (Educause 2016). Development of IMS Caliper was launched in 2013 with the publication by IMS of the Learning Measurement for Analytics Whitepaper (IMS Global Learning Consortium 2013). The whitepaper, reflecting the strategic interests of the IMS membership, discussed Caliper in terms of the growth of digital education and “a continued heightened interest in, and now demand for, accountability regarding the ability to measure and analyze this enriched online learning activity”. The whitepaper proposes an 'edu-graph' of the whole range of educational data, and Figure 1, below, shows the initial IMS focus areas within this wider domain.

[8] http://scorm.com/scorm-solved/scorm-engine/
[9] http://scorm.com/scorm-solved/scorm-cloud-features/
[10] https://github.com/AICC/CMI-5_Spec_Current
[11] @cmi5spec #cmi5
[12] https://www.imsglobal.org/membersandaffiliates.html

In addressing these areas IMS sets out to complement and leverage its existing set of specifications: "Substantial pre-existing work e.g. Learning Tools Interoperability™ (LTI)™, Learning Information Services (LIS), Question and Test Interoperability™ (QTI)™ has been done to standardize the learning activity encapsulation and context that can be leveraged, but it needs to be extended to engage learning measurement" (IMS Global Learning Consortium 2013). Somewhat confusingly, IMS has also had a parallel activity to Caliper, called RAM (Real-time Analytics Messaging) "to implement real-time, actionable messaging alerts". This work has now changed its name to IMS HED Analytics group, and it is said to relate "to requirements to leverage a more minimal event with a free-form payload" (IMS Global Learning Consortium 2015e)

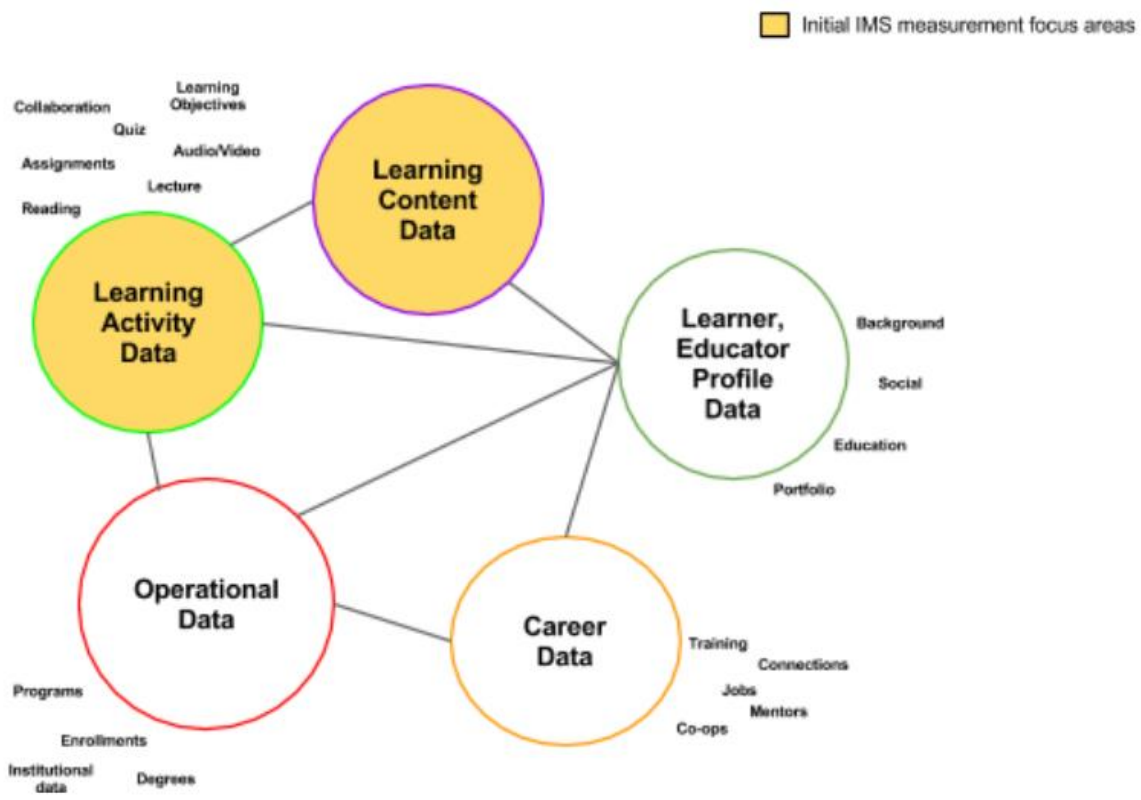

Figure 1: The comprehensive "edu graph" data model. Source: (IMS Global Learning Consortium 2013)

An overview of the Caliper specification

Version 1.0 of the Caliper specification was published in October 2015, and promoted as "the world's first interoperability standard for educational click stream data" (IMS Global Learning Consortium 2015f). It aims "to provide Learning Metric Profiles as standardised descriptions of actions and related contexts; creating Learning Sensor APIs and Learning Events drive to be able to aggregate metrics; and leverage of existing IMS specifications, like Learning Tool Interoperability (LTI) specification, Learning Information Service specification , and Question & Test Interoperability specification". According to IMS (IMS Global Learning Consortium 2015b) Caliper's principal contributions are that it:

- Creates IMS Learning Metric Profiles to establish a basic, and extensible, common format for presenting learning activity data gathered from learner activity across multiple learning environments. Metric Profiles provide a common language for describing student activity. By establishing a set of common labels for learning activity data, the metric profiles greatly simplify exchange of this data across multiple platforms. While Metric Profiles provide a standard, they do not in and of themselves provide a product or specify how to provide a product. Many different products can be created using the same labels established by the standard.
- Creates the IMS Learning Sensor API™ to define basic learning events and to standardize and simplify the gathering of learning metrics across learning environments.
- Leverages and extends the IMS LTI™/LIS/QTI™ standards thus enhancing and integrating granular, standardized learning measurement with tools interoperability and the underlying learning information models, inclusive of course, learner, outcomes and other critical associated context.

The Caliper specification is composed of three documents (IMS Global Learning Consortium 2015b)

- Caliper Analytics v1 Best Practice Guide
- Caliper Analytics v1 Implementation Guide
- Caliper Analtyics v1 Conformance Guide

In the following outline of Caliper we describe the main elements of the specification, paraphrasing and quoting from the Best Practice Guide and the Implementation guide. Detailed citations are not provided in this description in order to increase readability, and readers are referred to the Caliper documentation for authoritative information about the specification.

Learning Activity: A *Learning Activity* in Caliper is any activity that can be a component of a learning sequence in a digital learning environment. A *Learning Activity* is typically equivalent to a lesson.

Caliper SensorAPI™: The *Caliper SensorAPI* defines the way that learning applications (for example, a Learning Management System, or a publisher's content) can interact with the learning analytics services that are offered by Caliper.

Caliper Sensor: A *Caliper Sensor* is a piece of code that can be used by programmers to include Caliper functionality in their learning applications. The code takes care of the relationship between the host application and Caliper services, and makes it much faster and easier to adopt Caliper. Sensors have been implemented in Java, Javascript, PHP, Python, Ruby and .NET, in order to support a wide range of applications.

Metric Profile: *Metric Profiles* define the types of learning activities which can be handled by Caliper. They offer a common format for grouping learning activity data. The data is classified and managed according to a list of learning activity concepts included in the specification. There is a *Base Metric Profile* which includes entities and attributes that are useful in describing all other Metric Profiles (for example name and keywords). The other profiles are *Session*, *Annotation*, *Assignable*, *Assessment*, *Outcome*, *Reading* and *Media*. It should be noted that there is an extensions property

which can be used to add properties to the *Base Profile* in order to track aspects which not have been foreseen by the specification. Each *Metric Profile* includes three types of information:

- The Entities that participate in Learning Interactions (e.g. *Person*, *Assessment*, *Video*, etc.). In the case of the *Reading* profile these refer to properties drawn from the ePub specification (e.g. ePubVolume)
- *Actions* indicate the actions that can be carried out as part of a *Learning Interaction*. For example in the *Reading* profile the available actions are *Searched*, *Viewed* and *Navigated To*.
- Events capture the *Entities* involved in a learning event, and the *Actions* that are performed. For example the *Reading* event includes the attributes *Actor*, and *Object* (a digital resource in most cases)

In order to do useful work with *Metric Profiles* the data that they generate has to be held in an *Event Store*. Caliper does not formally include an open, standards based event store/LRS in its initial scope. However, a reference *EventStore* implementation has been provided, which is intended as a development/test/demo environment rather than as a component of a production Caliper system.

There is also an *Engagement Scenario* which is not a *Metric Profile* per se, but rather a common use case that applies a blended collection of metrics and context derived from other metric profiles. The scenario contains a list of *Events* and *Actions* drawn from the current set of *Metric Profiles* that indicate minimum student engagement with *Learning Activities*. All attributes/objects (e.g. *actor*, *action*, *object*, *startedAtTime*, *endedAtTime*, *duration*, etc) of *Events* are implicitly part of the *Engagement Profile*. Figure 2 provides a high level representation of the Caliper environment.

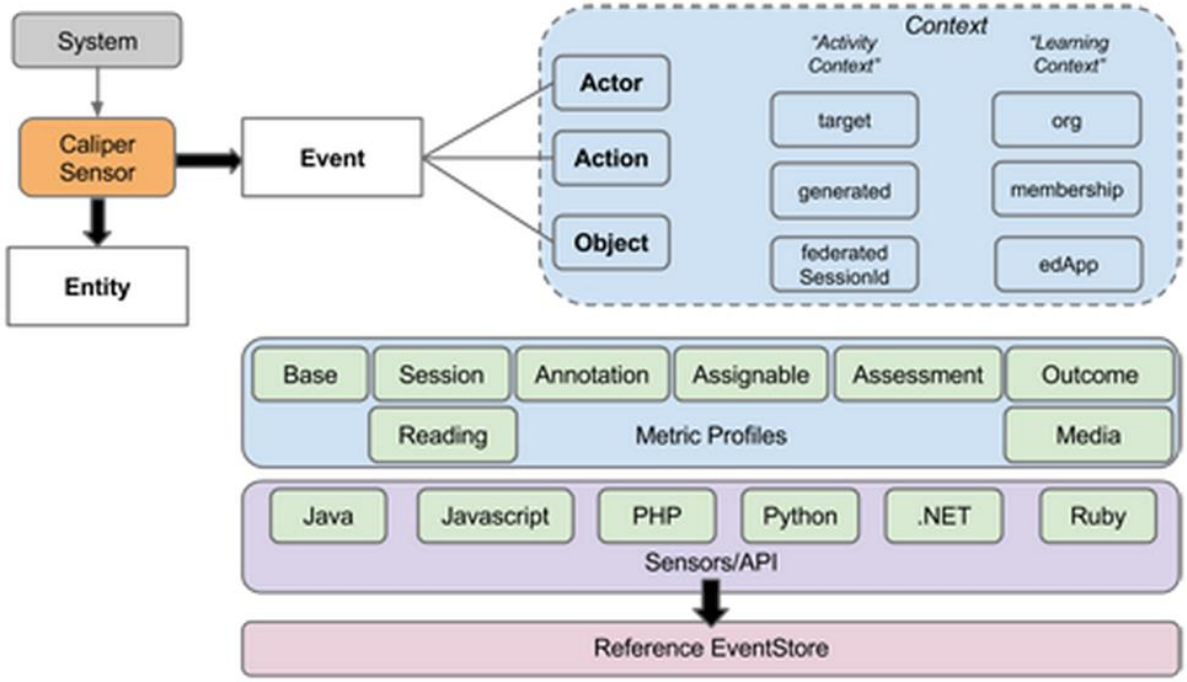

Figure 2: high level representation of the Caliper environment

It is not anticipated that all adopters will implement all of the Metric Profiles. The advice of the Best Practice Guide is that

> …when you begin implementing Caliper you should compare your application's features with the metric profiles and implement the ones necessary to capture the user's activities based on your features. For example a Quizzing tool would want to implement base, session, assessment, assessment item and outcome metric profiles. An eReader would at a minimum implement base, session and reading metric profiles. (IMS Global Learning Consortium 2015c)

It is however expected that the selection of Metric Profiles which are implemented in a particular system will work together to provide a richer picture of activity than could be achieved with any one of them independently, as indicated in Figure 3.

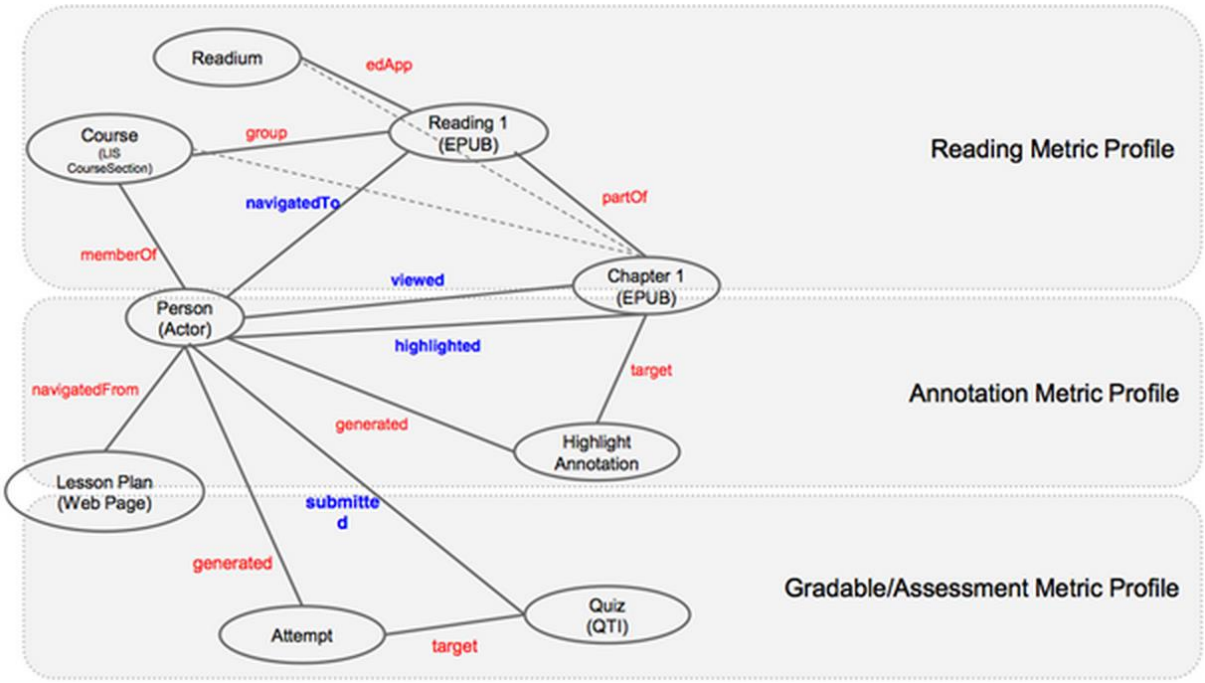

Figure 3: Illustration of Metric Profile Interactions. Source: the Caliper Implementation Guide

C-BEN and the TIP Project

The Competency-Based Education Network (C-BEN) is "a group of colleges and universities working together to address shared challenges to designing, developing and scaling competency-based degree programs" (Competency Based Education Network 2015). C-BEN has partnered with IMS Global to seek a solution to the problem of interoperability of competence definitions. The Technical Interoperability Pilot[13] has been set up to support this collaboration, with funding from the Bill and Melinda Gates foundation. Many aspects of this work are peripheral to LA interoperability, but one aspect is relevant. Leuba (2015) argues that "competencies are not managed in the same way as courses, with a unique competency code and related competency statement that can be added or changed and removed as needed". In response to this, the top use case to be addressed by TIP is "Managing competencies using a unique key, in an integrated database, including the course-competency relationship(s)" (Leuba 2015). No solid results are yet available from this work, but it can be imagined that, if successful, it would offer a possible route to classifying the result of a learning activity. In this way it is relevant to the pedagogical interoperability problem raised by LA interoperability specifications. Indeed, while C-BEN is committed to collaboration with IMS Global,

[13] https://www.imsglobal.org/initiative/enabling-better-digital-credentialing

they would also be a good fit for a Community of Practice in the context of xAPI. In relation to this, Aaron Silvers commented that the Data Interoperability Standards Consortium (DISC) "would welcome their involvement and we'd be happy to support C-BEN any way we can" (A. Silvers, January 5 2016, personal communication).

Adoption of Caliper and xAPI

There has been a great deal of activity in the field of LA in recent years, with institutions exploring the potential for LA to transform their activities. As (Siemens et al. 2013) suggests, this is a gradual process involving progress through a number of stages. Only in the final stage do Siemens et al. expect to find sector transformation with data sharing capacities.

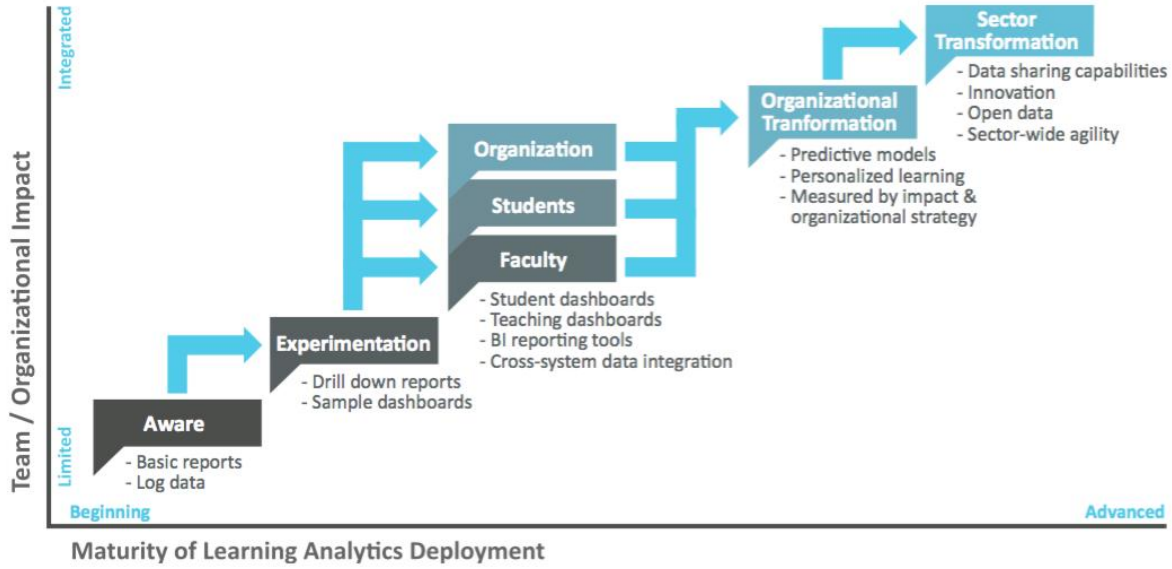

Figure 4: Learning Analytics Sophistication Model. Source: (Siemens et al. 2013)

This is borne out by the experience of LACE. While there are many institutions and consortia implementing various LA techniques, deployments of LA interoperability methods are thin on the ground. This is not entirely surprising, given that interoperability specifications have only recently become available for experimentation, and that the architectures that support them are currently emerging. In this section we outline the emerging adoption of interoperability systems for LA.

The adoption landscape for IMS Caliper

Of the three documents that compose the IMS Caliper specification, one is the Conformance Guide. This is intended "to ensure high levels of interoperability by testing and evaluating adherence to the Caliper standard framework ... The conformance certification process involves testing for the ability to support one or more of the Caliper Event metric profiles" (IMS Global Learning Consortium 2015d). The certification process is only open to IMS members, and is carried out using a software certification suite hosted by IMS. Thus the certification process is "particularly aimed at maximising system interoperability" (ibid) among the systems provided by IMS members. Interestingly "IMS Caliper Analytics certification demands features and capabilities beyond those which are strictly

required by the specification" (ibid), which is presumably a result of a focus on the interoperability of particular software implementations of Caliper Sensors.

From this perspective, adoption of Caliper means demonstrating conformance with the specification by successfully passing the tests hosted by IMS. It is possible to make use of the specification without seeking certification of conformance, but the importance given to conformance in the specification suggests that IMS will give strong strategic support for this process. It also suggests that the specification is targeting the needs of larger vendors, and institutions that have the resources to proceed through a certification process, and which, it is hoped, will be able to use certification to gain competitive advantage. In the press release that accompanied the publication of Caliper, Rob Abel, CEO of IMS Global, made this approach clear saying:

> The goal of Caliper Analytics is to reduce the cost of obtaining quality analytics data from digital educational products by orders of magnitude. … We anticipate that many more organizations will soon follow suit as more and more institutions ask for Caliper conformance to enable consistent access to learner data. (IMS Global Learning Consortium 2015g)

The publication of the Caliper specification was accompanied by the announcement that "nine leading EdTech products have achieved conformance certification to the newly released Caliper Analytics™ standard". On October 20th IMS announced that

> Several IMS Global Contributing Member organizations have demonstrated leadership and support for Caliper by being among the first to implement Caliper into their products and complete conformance certification. Those organizations include Blackboard, D2L, Elsevier, Intellify Learning, Kaltura, Learning Objects, McGraw-Hill Education, University of Michigan and VitalSource Technologies. (IMS Global Learning Consortium 2015f)

IMS has also announced that the Unizin consortium of 11 public universities is partnering with IMS Global in an effort to drive the adoption of the Caliper Analytics standard.

> Unizin and IMS Global will collaborate on developing a Simple Content Use Metric Profile to define the way data is shared using Caliper. This profile will provide a standardized template for each type of learning event, down to the most basic user interactions with course materials. The two organizations described the synergy this way: Unizin can help speed up adoption of the Caliper Analytics standard by Unizin member institutions. IMS Global can then benefit from feedback from the faculty and staff at Unizin member schools, who can provide real-world Caliper applications and validated metric profiles. In turn, Unizin will be able to offer flexibility and autonomy to members and provide a community forum for assessing and using the Caliper standard in the Unizin ecosystem. (Raths 2015)

Given that Caliper was published less than a year before this paper, it is to be expected that adoption is still at an early stage, and that teething problems are to be found. For example, Yong-Sang Cho (Cho 2015) found that implementing IMS Caliper Analytics in a Korean context created bandwidth issues, as implementing the specification led to the need to store a lot of redundant information, and the specification lacked a structure to make data storage more efficient. The degree to which any such issues have long-term implications remains to be seen. Moreover, given that a number of major eLearning organisations have already achieved conformance, the commitment of Unizin, and the large number of contributing members of IMS who are likely to be

interested in making use of the specification, it seems likely that it will, at least, achieve a viable level of adoption among large vendors.

The adoption landscape for xAPI

At the time of writing there are 180 organisations mentioned as xAPI adopters on the TinCan API website[14]. While it is not clear what the threshold is for inclusion on this page, there is clearly a wide community of people and organisations who are working with the specification. In this report we cannot explore what all these organisations are doing with the specification. We do however draw attention to some important work being done to move the specification forward.

Perhaps the most important aspect of adoption is the use of xAPI in the architectures under development by **Apereo** (Apereo Foundation 2016) and **Jisc** (Sclater 2015), as this creates an environment where large scale use of the specification by education institutions becomes a practicable option. The Apereo Foundation is not, strictly speaking, the promoter of the Open Learning Analytics (OLA) architecture. Rather, it provides an incubation and collaboration service to those who are driving development and adoption, though, of course, it has a common purpose in providing effective open source software for education. As a result the early adopters of the Apereo OLA architecture are those institutions that are involved in the development of the system, in one way or another. Moreover, even though Apereo OLA aims towards an integrated system, it is the case that a 'pick and mix' approach is perfectly practicable, and indeed entirely compatible with a standards based approach. The Jisc Open Learning Analytics Architecture (OLAA), which has a close symbiosis with Apereo, demonstrates this clearly, enabling adopters to choose from a mix of open source systems from Apereo, and proprietary technologies from vendors. Thus each component of the Apereo OLA will have its own adoption curve, while the shape of the architecture will evolve in response to the adoption of components and introduction of new components such as the planned Jisc consent system. It is too early to be sure of the prospects for the Apereo and Jisc architectures, but there appears to be substantial momentum behind the initiatives, and current signs are promising. Success for these initiatives would have a strong positive impact on adoption of xAPI by placing it in the context of an ecosystem of integrated applications. Caliper, which will also be supported by the Jisc OLAA, will also benefit, though to a lesser extent that xAPI because Caliper is embedded in the emerging suite of IMS compliant specifications and implementations, with all the benefits and constraints that this may imply.

A number of companies are working on xAPI implementations, many of which participate in the community around and xAPI Quarterly[15] and the Connections Forum[16], which is a particularly valuable source of information on xAPI implementations. There is also an xAPI group in Australia coordinated around the TinCan at Work[17] community website.

The Connected Learning Analytics Toolkit has made use of xAPI as part of the project 'Enabling connected learning via open source analytics in the wild: learning analytics beyond the LMS'[18]. The

[14] http://tincanapi.com/adopters/
[15] http://xapiquarterly.com
[16] http://connectionsforum.com/
[17] http://ideasatwork.com.au/blog/category/ideasatwork/tincanatwork/
[18] http://www.olt.gov.au/project-enabling-connected-learning-open-source-analytics-wild-learning-analytics-beyond-lms-2014

project is sponsored by the Australian Government's Office for Learning and Teaching, and is led by Kirsty Kitto. She explained in a LACE interview (Griffiths 2015) that the underlying concern is that in collaborations between technologists and pedagogic experts the early adopters of LA among the pedagogic experts tend to be working outside the confines of the Learning Management System. However, "LA is a capability usually provided by LMS vendors, and this makes it difficult to provision LA capabilities beyond the LMS" (Griffiths 2015). To address this problem the CLA toolkit "helps students and teachers to harvest data about their activities in standard social media environments, and then provide(s) immediate feedback and reports" (ibid). This creates the need to collect comparable data from multiple platforms. According to (Bakharia et al. 2015)

> The CLA toolkit is open source (GPL3.0), and implemented in python, using a Django framework. It consists of two main components:
>
> - Data Collection is achieved by interfacing with standard social media APIs to retrieve specific data about student participation in a pre-defined learning activity. This data is stored in a Learning Records Store (LRS) using xAPI format. ...
> - Analytics and Reporting are enabled by pulling data out of the LRS and storing it in a secondary database (presently PostgreSQL) which provides full functionality for querying.

This brief survey of the work being carried out with xAPI makes it clear that there is interesting and innovative work being done with the specification. Whether this will create critical mass for adoption of the specification is not yet clear. Robert Gadd of OnePoint gave an assessment of the state of adoption at the 2015 xAPI Camp – Orlando, at University of Central Florida, which may apply to LA specifications in general. This is only one person's view, but his combination of caution combined with enthusiasm for the possibilities facilitated by xAPI seems realistic to us.

> …the trough of disillusionment from Gartner, we feel that we're in that to a great extent. We have spent a lot of time and effort to create things that people seem to be interested in, and as a vendor I'm seeing a lot of people asking and having check boxes about it. But at the end of the day we don't see a tremendous amount lot of mass scale adoption of what this is. I think the industry is waiting, and I'm glad that the vendors are starting to catch up across the board. We think this is a far more rational way to collect and manage all of this data. (transcribed from (Gadd 2015).

A barrier to the adoption of xAPI has been a lack of conformance and certification. This concern now seems to be easing with the launch in August 2016 of initiative from ADL and DISC to accelerate the development of these aspects of the specification. As Silvers stated in a presentation at the launch, conformance has been mediated by social interactions between developers, and so "There is no realistic way, currently for a third party to evaluate the interoperability of these systems, and for consumers of LRS software who don't participate in these forums and calls" (Silvers 2016). The development process is entirely open, and an ambitious programme has been established, with LRS Conformance Requirements and Certification Testing Program Recommendations slated for delivery by end-of-year 2016.

Initial moves towards convergence between Caliper and xAPI

In the view of many there is a role for both xAPI and Caliper. This is the position taken by Jisc OLAA, and forcefully expressed by Kitto.

> Caliper is very much oriented around the LMS, and it doesn't support anything beyond that. … But it is important because dealing with the data in an LMS is a horrible experience. If Caliper can deal with that then that will be really good. So I hope that together the two specifications will be able to solve both problems: Caliper can hide the complexity of data structures in LMSs, and xAPI has the flexibility to knit together data from a wide range of devices and platforms. (Griffiths 2015)

More specifically, Kitto (2015) has suggested looking at the W3C Activity Streams 2.0 specification as both a means for mapping between the xAPI and Caliper specifications, and as a way to introduce more machine readable structure to the specification profiles (recipes) through use of JSON-LD (Json for Linked Data) , which is part of the W3C specification. (JSON-LD is already part of IMS Caliper as all Caliper entities include a JSON-LD @id, @type and @context to request the data.) The issue of enabling a crosswalk between the two specifications to promote interoperability has also been put on the agenda of formal standardisation (ISO/IEC JTC 1/SC36 WG8).

As we reported in (Griffiths et al. 2016), at the end of 2015 it was unclear if IMS Global was interested to start harmonisation of the two specifications at the current stage. Aaron Silvers, who has had a leading role in developing xAPI has described the practicalities of attempting collaboration:

> What I've heard is from third parties vaguely relating IMS Caliper to me because the stipulations for confidentiality that IMS appears to demand on its members keep people from sharing much of anything informative around the spec. So, urged by several people in and around our community, we attempted to join IMS over a month ago specifically to develop a profile for IMS Caliper for the xAPI community that would translate whatever Caliper is so there'd be a means to go between the two worlds. We were told, quite bluntly, not to bother joining IMS. We (at least Megan Bowe and I) and/or our rationale (building a bridge between IMS Caliper and xAPI) are not welcome. (Silvers 2015)

We echo Kitto's description of the benefits of having a specification which can deal with the complexities of data structures in LMS systems. We also understand the motivation of IMS Global and the vendors who work within it to keep the development process closed, and to maintain control of derivative versions of the specification (whether or not we agree with this policy). Within the constraints of this policy, we are pleased to note that in recent months substantial progress has been made on resolving the impasse described by Silvers, above. On July 25th 2016 ADL announced that

> ADL recently joined the IMS as a contributing member. Both organizations have expressed a renewed interest to work together and collaborate on learning technology standards and research areas of mutual interest. ADL and IMS also recently began discussions about the possibility of aligning the specs and whether it is even practical or achievable. …the final outcome will be based on how much harmonization, if any, can be accomplished between the two specs. (Haag 2016)

A public meeting was also announced to kickoff future collaborative efforts to explore the differences between xAPI and Caliper. It remains to be seen what will emerge from these efforts, but these are very positive developments, which merit the active support of policy makers and managers.

Contrasting xAPI and Caliper

There are many parallels between xAPI and Caliper, and, as we have seen, there are initiatives to explore the possibility of harmonising the specifications. Nevertheless, institutions need to adopt a stance with regard to the ecosystems which are growing up around the two specifications. This may be to commit to one or the other, or to make use of both. We now suggest four differences between the specifications, which are intended to spark reflection on the strategic implications of LA specifications for institutions.

Difference 1: Derivative works. The licences adopted by IMS Caliper and by xAPI are significantly different in terms of the ability to create derivative versions of the specification.

- **IMS:** "No right to create modifications or derivatives of IMS documents is granted pursuant to this license. However, if additional requirements (documented in the How to Use IMS Documents are satisfied, the right to create modifications or derivatives is sometimes granted by the IMS to individuals or organizations complying with those requirements." (IMS Global Learning Consortium n.d.)
- **ADL:** Apache 2 license. "Subject to the terms and conditions of this License, each Contributor hereby grants to You a perpetual, worldwide, non-exclusive, no-charge, royalty-free, irrevocable copyright license to reproduce, prepare Derivative Works of, publicly display, publicly perform, sublicense, and distribute the Work and such Derivative Works in Source or Object form." (The Apache Foundation 2004)

As we have discussed above, the use of the Apache license means that ADL, and now DISC, does not need to give permission to IEEE and others to make a standard from the specification. Nor is there any obstacle to derivative specifications, should there emerge community needs which are not well met by the current specification. IMS Global, on the other hand, seeks to keep close control over the use of its specifications. Policy makers and managers will have to decide if the development of true standards is important to them, and capability to create derivative specifications is valuable.

Difference two: governance. Governance of Caliper is by the IMS consortium, which is a subscription organisation. Institutions that are not members of IMS have very little knowledge of the governance process. xAPI is owned by the Data Interoperability Standards Consortium (DISC), which was established in 2016, as a not-for-profit organization in the State of Pennsylvania, USA. It is the owner of xAPI, and its immediate task is to provide industry stewardship and governance of the specification, maintain the specification as open source, and to support working groups and interests (Data Interoperability Standards Consortium 2016). While it is too soon to say what policies will actually be adopted by DISC, it seems likely that governance of the specification will follow the open source model, and be substantially more open than is the case for IMS Caliper. Policy makers and managers should consider whether one or other of these two models of governance is likely to produce long term outcomes that favour their organisation.

Difference three: core vocabularies versus community driven approaches. IMS Caliper comes with a set of metric profiles. The development process for the specification has not been made public, but we can safely assume that these metric profiles cover the common use cases put forward by the vendors who make up the majority of IMS' contributing members. There is an extension point for

additional metric profiles, but these will be ad hoc, and not part of the conformance profile. The press release accompanying the launch of IMS Caliper identified its goal as being "to reduce the cost of obtaining quality analytics data from digital educational products by orders of magnitude" (IMS Global Learning Consortium 2015g). The implied value proposition might be imaginatively summarised as: *Most institutions make use eLearning software drawn from a relatively small group of suppliers. IMS Global has developed a specification that will facilitate your use of LA with these suppliers. Why waste your time and money messing about with more complex solutions, when we can offer you a ready made system that will meet your needs.*

xAPI has gone down the opposite route. In progressing from version 0.90 to 0.95 of xAPI, ADL decided to drop core vocabularies from the specification and go for an open framework. This added complexity to the infrastructure, but ensured its openness and responsiveness to local conditions. For any given domain, *Communities of Practice* are expected to define and share the structure of xAPI statements and vocabulary as profiles (also known as *recipes*). Some profiles have been developed, and others are underway, though whether this effort is sufficient remains to be seen. For example, the Jisc OLAA includes a profile for attendance, and has developed a VLE with a plugin for Moodle and Blackboard, with profiles for library activity data, and student self declared data to follow. In Australia the Connected Analytics project has produced a profile for analytics beyond the LMS (Kitto & Bakharia 2015). For many this adaptability is a key attraction of xAPI, as Kitto has expressed "If you want to talk about a unified language for LA then you have to involve the whole community. You can't develop it in private and then dump it on everybody" (Griffiths 2015). Nevertheless, there is work to be done to make this approach work. Bakharia et al. (2015) describe the need for a formal schema for processing statements that adhere to a profile, and the lack of a RESTful interface to perform aggregate queries (e.g., counts of verbs and object) against the statements in an LRS. ADL has a draft specification for some of the vocabulary handling, working with their registries and dealing with activity streams verbs. This specification is expected to be made available shortly after the publication of this report.

These detailed technical issues, which emerge out of pilot implementations, are both an indication of the work which remains to be done with xAPI, and also an example of how such problems can be identified and addressed within an open xAPI community. Educational policy makers and managers will have to decide whether the flexibility of xAPI, and the important role which Communities of Practice play, are of importance to them, or if the support for a set of established mainstream use cases in IMS Caliper is of more practical value. The implied value proposition for xAPI might be imaginatively summarised as: *Your educational environment, and your institution is unique. Why let companies in another continent decide what how your relationship with your learners should be managed? By adopting xAPI you can leverage a network of institutions around the world that are developing and deploying systems that recognise the variety of technical and pedagogic needs in LA. Only flexible and open systems can provide the necessary breadth of vision needed for you to meet your unique needs.*

Difference four: data protection. A potential issue is that data privacy has a much higher profile in Europe than in the USA, where both IMS Caliper and xAPI have their origin. In Germany and Switzerland, there are strong legal controls both on the collection of data, and on its storage. Moreover the recent ruling on Safe Harbour by the European Court of Justice (2015) will bring about

changes in the way in which European data is handled that are not yet clear. IMS Caliper includes a Learning Event Store, while Apereo OLA includes a Learning Record Store. In architectural terms either of these could have controls over the collection, storage and access to data. However, the Apereo community seems to be taking the lead in addressing this issue, and the Jisc OLAA includes a Consent component. One might also wonder whether the business models of the vendor community are compatible with some of the more radical approaches to data protection which have been proposed, for example, by the Open Personal Data Store (de Montjoye et al. 2014). Policy makers and managers should consider if data protection issues are important to them, and should look carefully at the emerging support provided by the two ecosystems.

In all likelihood there will be a place for both specifications. As Kitto suggested in a LACE guest blog post, xAPI and IMS Caliper will be developed to serve specific needs "in their natural niches".

> xAPI is really strong in the professional learning context, and for recording events that occur beyond the LMS (or in the wild, where most of our ongoing lifelong learning interactions occur). (...) IMS Caliper will probably end up a pretty standard solution for the more defined parts of the learning ecosystem, by which I mean enterprise sized LMSs and large scale applications that want to interact with them easily (Kitto 2015).

For this to be a satisfactory solution for institutions, it is important that the outputs of the two specifications can mapped against each other. With this in mind, it is encouraging that one of the goals of the ADL Experience API (xAPI) and IMS Caliper Discovery Review (Haag 2016) is to "Determine if convergence into one specification and eventually, a standard is possible, and if not then if a crosswalk of data models a suitable option". We recommend that all interested parties insist that this is indeed achieved.

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About ...

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About this document

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The LACE project brings together existing key European players in the field of learning analytics & educational data mining who are committed to build communities of practice and share emerging best practice in order to make progress towards four objectives.

> *Objective 1 – Promote knowledge creation and exchange*
> *Objective 2 – Increase the evidence base*
> *Objective 3 – Contribute to the definition of future directions*
> *Objective 4 – Build consensus on interoperability and data sharing*

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