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Learning Analytics Interoperability: Requirements, Specifications and Adoption

Public Deliverable – D7.4

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Abstract:

Interoperability specifications and architectures for learning analytics are rapidly evolving, but the education sector is poorly prepared for understanding the implications of these developments. The current state of specifications and architectures is surveyed, with a particular focus on xAPI, IMS Caliper, PAR, Apereo and Jisc. The readiness of user groups to engage with the development process is discussed, and found to be weak. Finally the report proposes some ways of approaching the formulation of strategic choices on interoperability strategy that institutions are facing.

Contents

1. Introduction

This report emerges from the activity on two tasks in LACE work package 7: Task 3 seeks to build a consensus on a description of core elements and mappings, while Task 4 has as its objective a prioritised roadmap for development of shared data repositories for learning analytics and learning science research. The scope of the report includes requirements, explores options, and makes recommendations in respect of high level system architecture, sustainability, cultural/legal/ethical issues, etc.

In the LACE Description of Work it was foreseen that work on tasks 3 and 4 would lead to a CEN Workshop Agreement. As discussed at the first annual project review this did not prove to be a feasible objective, for two reasons.

Firstly, the CEN Workshop on Learning Technologies has been disbanded[1], and no equivalent European forum currently exists.

Secondly the idea of a unitary roadmap has been questioned, given the highly situated nature of learning analytics. This was argued in LACE Deliverable D7.2 'Data Sharing Requirements and Roadmap' (Cooper & Hoel 2015), which offered a high level description of requirements and design options. One of the conclusions of D7.2 was that:

> The variety of aims for data sharing (section A 2 Exploring aims for data sharing) makes clear that "data sharing for learning analytics" is not a single idea and, in retrospect, the task set out in the LACE Description of Work to "develop a prioritised roadmap for development of shared data repositories for learning analytics and learning science research" could have been expanded into an entire project. Indeed, the idea of "a roadmap" became questionable as the range of possible aims for data sharing was explored because the balance of emphasis between the issues varies. Hence, we conclude that, as groups of stakeholders marshal interest around certain aims, each should expect to develop their own roadmap.

Consequently, as discussed at the first annual project review, the present report provides a detailed survey of current interoperability initiatives, in order to provide input to the development of such roadmaps, and to inform the choices of educational policy makers and managers.

1.1. Aims and objectives

The focus of this report is on technical issues related to the specifications, architectures and infrastructure needed to implement solutions for learning analytics (LA) in different educational settings. Increasing amounts of data are being captured, exchanged and analysed by educational institutions. LA has the potential to integrate these data with the tools and legacy systems that are in use in schools, universities and workplaces today, and use the resulting applications to enhance the performance and results of both institutions and the people who work and study within them. However, LA may also have the potential to disrupt current usage of technology as users discover flaws and gaps in current architectures, for example due to issues of ownership and control of data, trust, or of ethical codes of use not being properly addressed.

The use made of these capabilities can determine the success of an institution, and so is of direct interest to those responsible for institutional strategy, while the requirements of learning analytics

[1] See https://www.cen.eu/work/areas/ICT/eEducation/Pages/WS-LT.aspx

systems are exercising an increasing influence on decisions on technical infrastructure. Consequently the interoperability of learning analytics data and representations takes on significant strategic importance. Interoperability can ensure that all the elements of the technical ecosystem can work together efficiently in gathering data and analysing them, and so that opportunities for insight are not lost. Interoperability also works to counteract lock-in to single providers and to legacy systems, two problems that can both constrain the functionality made available to learners, teachers and managers, and also increase costs.

In the light of this central role for learning analytics interoperability, the aim of this document is to provide decision makers at all levels of education with the information that they need to make informed judgements on learning analytics interoperability.

In order to achieve this aim, the following objectives will be addressed:

- Outline the technical issues raised by the LA interoperability process in a way which is accessible to policy makers and beneficiaries
- Document the current state of development of LA Interoperability
- Set out the decisions to be made by educational policy makers and managers when dealing with technical interoperability strategy for LA.

1.2. Audience

This deliverable is addressed to:

- Anyone who is required to make decisions on educational or training infrastructure
- Policy-makers who are responsible for the regulatory framework governing analytics
- Funders who are responsible for allocating resources to research and development in this area.

It does not set out to resolve the challenges that are encountered by those developing interoperability specifications and architectures for learning analytics. But the authors hope that the report will be valuable to them by identifying alignments and points of divergence within the learning analytics interoperability landscape.

1.3. Scope

The scope of learning analytics (LA) is not uncontested. Writing in the Educause Review, Van Barneveld et al. (2012) distinguish between:

> **Academic Analytics**: a process for providing higher education institutions with the data necessary to support operational and financial decision making (adapted from Goldstein and Katz)."
>
> and
>
> "**Learning Analytics**: The use of analytic techniques to help target instructional, curricular, and support resources to support the achievement of specific learning goals (adapted from Bach).

On the other hand the Jisc Code of Practice for Learning Analytics does not make this distinction, and defines LA more generally, stating that "Learning analytics uses data about students and their activities to help institutions understand and improve educational processes, and provide better support to learners." We do not suggest that there is any deep divide in approach between these and other definitions, but we take the opportunity to make readers aware of possible confusion, and to clarify that we will be taking an inclusive view of the scope of LA.

LA typically involves bringing together data from a range of sources to create a rich picture of the learners' activities, which can then be analysed. In this sense most of the field of LA involves interoperability of data in one form or another. Consequently the criteria for technologies and standards being within or out of scope may be blurred, depending on the aspects of the architecture that are under consideration. A case in point is metadata standards. These have been around for some years, and are used in all kinds of learning technologies. Are these part of the interoperability landscape for learning analytics? One might assume that they are not. But if you are building a recommender system acting upon the insights gained by analysing activity data from a number of sources, then metadata standards may be essential in recommending relevant resources. The same could be the case for competency standards, and a host of other standards developed within education. Consequently the inclusion of LA modules in an existing educational architecture is, to a large extent, about making use of the data that are already there: in the log files of the LMS, in the Student Information System, in the Library system, etc. A more significant challenge is to add new data sources, e.g., self-declared activity data from the learners.

Learning analytics is now moving out of the research labs into schools, universities and vocational training on a large scale. In this report we want to compare and contrast technical architectures, record evidence of use, and carry out gap analysis in order to make an informed, if provisional, judgement on where time and money will or should be directed to ensure that this move is strategically well directed, and operationally effective. However, we must realise that we are at a very early stage in the process, and the standards support strategy of some vendors may be limited to following the aspirations set out in a white paper. As of yet there is no agreed map of the technical LA space; indeed, it is impossible to be sure that we have identified who will be the most influential stakeholders for the design of this space. However, a picture is emerging of the overall landscape, with some features becoming clearer while others remain shrouded in mist. It is this emerging picture which we will report on in this deliverable. Much of the work on LA interoperability is being driven by vendors, and by the Higher Education (HE) sector, where large institutions have realised the strategic importance of the issue, and have both the leadership and research capacity to address it. The infrastructure itself is applicable across sectors, as are many of the strategic implications. However, in the section on requirements (below) we focus on the differing dynamics in the HE, Schools and Workplace sectors.

1.4. Structure

The title of this report, 'Learning Analytics Interoperability: Requirements, Specifications and Adoption', may suggest a sequential process that is not to be found in the case of LA interoperability. As we have argued above, LA systems build on the data which is already available, and are constructed from existing components, often without a conventional requirements gathering process. LA Specifications and architectures have arisen in response to the contingencies of the technologies being used, and to the needs of education as understood by the teams which are responsible for driving the work forward.

We therefore start our report with an analysis of the facts on the ground, i.e., the specifications and architectures that are currently gaining traction in the implementation of LA.

We then consider this landscape from the perspective of the requirements expressed or implied by user groups, and continue to survey current adoption.

We conclude by outlining an agenda for action by educational managers and policy makers.

2. The learning analytics interoperability landscape

2.1. Designing interoperability in a complex domain

It is important to recognise the dynamic nature of developing architectures and standards for learning analytics interoperability. The Learning Analytics in Australia project has described LA as comprising "complex phenomena, shaped by multiple, interrelated dimensions traversing conceptual, operational and temporal domains" (Learning Analytics in Australia n.d.) summarising (Colvin et al. 2015). The project, working in the area of HE, identifies six relevant dimensions, which we believe are generalizable to other sectors:

- institutional conceptualisations of LA
- the need for highly-focused and influential leadership
- an appropriate and sustaining structure supported by articulated vision and strategy
- technological competence
- stakeholder engagement
- context.

These dimensions were seen to combine in a non-linear, recursive, and dynamic process (ibid). Failure to recognise this complex landscape leaves one prey to supposing that interoperability is more mature than it really is. Similarly, a misplaced assumption that interoperability can be left to technical experts to resolve in the fullness of time may lead to disengagement from strategically important standardisation processes, or to delaying work until the ever-receding day when the specifications are felt to be sufficiently mature.

As part of D7.1 LACE published a "Specifications and Standards Quick Reference Guide" (Cooper 2014b), which provides an overview of the rather complex standards landscape. The standards groups involved are both industry consortia (e.g., IMS Global Learning Consortium), national standards bodies (e.g., Standards Norway) that are part of a formal standards track, and formal standards organisations like the European CEN/CENELEC and the international ISO/IEC (in which JTC 1/SC36 committee just started a working group on LA). It is important to note that those specifications with an explicit LA focus are only at the very beginning of a long standardisation process. Figure 1: Standards development is a never-ending cycle. Source: Egyedi (2008) represents the on-going cyclical process through which ideas are turned into a specification to be tested in real life applications, and are then fed back for revision and further development.

Many actors and communities are involved in this cycle, often in competition, making the "hand over" of work between the different stages in the development cycle a challenge. As argued in a LACE blog post, the achievement of consensus on how to describe a learning activity is a case in point, and we have seen that different organisational policies make it hard for the uninitiated to see what is going on (Hoel, 2015).

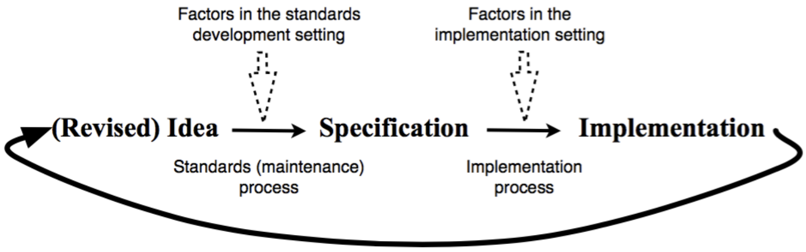

Figure 1: Standards development is a never-ending cycle. Source: Egyedi (2008)

This process raises many issues, two of which we highlight here.

Firstly, the criteria for assessing the infrastructure for learning cannot be limited to the purely technical. This can again be illustrated through the Learning Analytics in Australia project that has contrasted two clusters of LA implementations in HE institutions:

- Trajectory (Cluster) 1: LA was primarily focused on supporting retention activity
- Trajectory (Cluster) 2: LA was characterised by an emerging focus on pedagogy, curriculum, and learning.

The project concludes that

> ... the two trajectories did not only differ in how their learning analytics programs looked, both trajectories were underpinned by different conceptualisations of learning analytics, and their prioritisation, and readiness, of antecedent factors. Simply, how learning analytics was deployed (and performed) was strongly mediated by goals and drivers for learning analytics that appeared unique to each institution (Learning Analytics in Australia n.d.).

Given these different goals and drivers, a purely technical assessment of the effectiveness of LA is not possible. Moreover, there are many aspects of infrastructure which are often not captured by architectural diagrams. To give an example, from a functional point of view a cloud store, an institutional repository, and a personal store perform a similar technical task. However, from the perspective of the user, the types of interactions which they support may be very different, as may be the policy implications from an institutional perspective. As we will discuss below, current interoperability approaches make use of a 'Learning Record Store' that records and makes available for analysis the history of the learner's activity. Storage, however, is not a straightforward process, and raises many open questions.

- Are we talking about a huge, central learning record warehouse?
- Are we talking about long term storage?
- Would it be possible or useful to have distributed storage?
- Could each learner have a personal learning record store?
- What other processes are needed in order to run a storage service?

These open questions, seen from the perspectives of the various stakeholders, cannot be explored by carrying out a technical study. Because of this the loop of testing in Figure 1 should involve users at many organisational levels, taking their experiences and opinions as input into the design process.

Secondly, the LA interoperability process recursively changes the domain which it is operating on. Designs for interoperability are moulded by current practice in TEL and constrained by the existing infrastructure. But the designs also rethink the purposes to which TEL can be put, and the requirements for the systems that are to be constructed. The dialogue between these two discourses creates a dialectic which progresses, but which never reaches a stable state. We believe that this is as it should be, and that any attempt to impose a technocratic solution increases the potential for dystopian applications of technology.

2.2. The centrality of activities and activity flows

Learning technologies have always tried to capture data about the activities of the learners who use them, and it may be argued that the rise of learning analytics is a reflection of the huge increase in the quantity of this data with the introduction of new sensors and the use of Web technologies. In any event, whatever else LA may be, it seems clear that it is concerned with the management and processing of data about what learners do. A focus on learning activity can help to bring some coherence to the complex interoperability process we have outlined above, as it captures the object that is subjected to analysis. However, the term 'activity' has many meanings, including:

1. The name of a any repeated action (e.g. “reading is my favourite activity”)
2. Any kind of movement (e.g. “there is some activity in the computer lab”)
3. Carrying out a specific task (e.g. responding to an exam question)
4. The instructions for carrying out a task (e.g. 'activity' as defined in IMS Learning Design)
5. The opportunity to do something (e.g. a Wiki in Moodle is referred to as an activity).

This ambiguity raises pedagogical questions. What kind of activity is under discussion, and what kind of learning is taking place which it would be interesting to know more about? But 'activity' also has a technical meaning, for example the Experience API specification defines Activity as

> …a type of Object making up the “this” in I did “this”; it is something with which an Actor interacted. It can be a unit of instruction, experience, or performance that is to be tracked in meaningful combination with a Verb. Interpretation of Activity is broad, meaning that Activities can even be 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 (ADL 2013).

Much of the body of this report consists of an analysis of the various ways in which interoperability architectures and specifications represent learning activities, the data which they choose to collect about them, and the methods which they deploy to process them. Many aspects of this have strong links to earlier educational technologies. Others are new, including those issues related to data ownership and control.

3. The current state of learning analytics interoperability specifications

3.1. Some relevant prior specifications

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 this section we highlight two specifications, one describing activities and one describing predictive models.

3.1.1. Activity Streams

The work on defining a specification for activity streams started 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.

3.1.2. 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[2]. 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[3].

3.1.3. 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[4]). 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

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

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.

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 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 (Poltrack, 2014).

3.2. xAPI

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 which 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[5]. 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 version 1.0.2, as of November 20th 2015, 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 which 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.

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

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.').

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 kind 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[6].

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

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).

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 is aware that this "structured but incredibly open way of dealing with data" is the specification's "greatest strength and weakness" (Bowe 2013). The specification addresses this problem by explaining 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. As a result of the flexibility of xAPI there is also a need to add mechanisms to support interoperability beyond the specification itself. 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)

Thus the story of SCORM and its successor xAPI is a story about a learning activity tracking technology that proved to be too restrictive, both pedagogically and technically, and how easing the restrictions became the way to fix it. 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*.

CMI5

Werkenthin has argued that

> By itself, xAPI is not a replacement for SCORM. Instead, xAPI defines communication between a learning experience and the learning record store, or LRS. While most of us agree that the majority of learning occurs outside the LMS, there is still some formal e-Learning that will be maintained in the LMS, so a more modern SCORM is certainly needed. Now that ADL is taking over the cmi5 specification from the AICC, it is clear that cmi5 is the “next generation” of SCORM. (Werkenthin 2014)

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 one can think of CMI5 as the LMS use case for xAPI. It therefore 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.

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[7] and Scorm Cloud[8]. The CMI5 specification is open source and the current draft version if available on Github[9]. Development can be followed on Twitter[10].

3.3. IMS Caliper Analytics

3.3.1. 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[11]. 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. 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

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

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 2 shows the initial IMS focus areas within this wider domain.

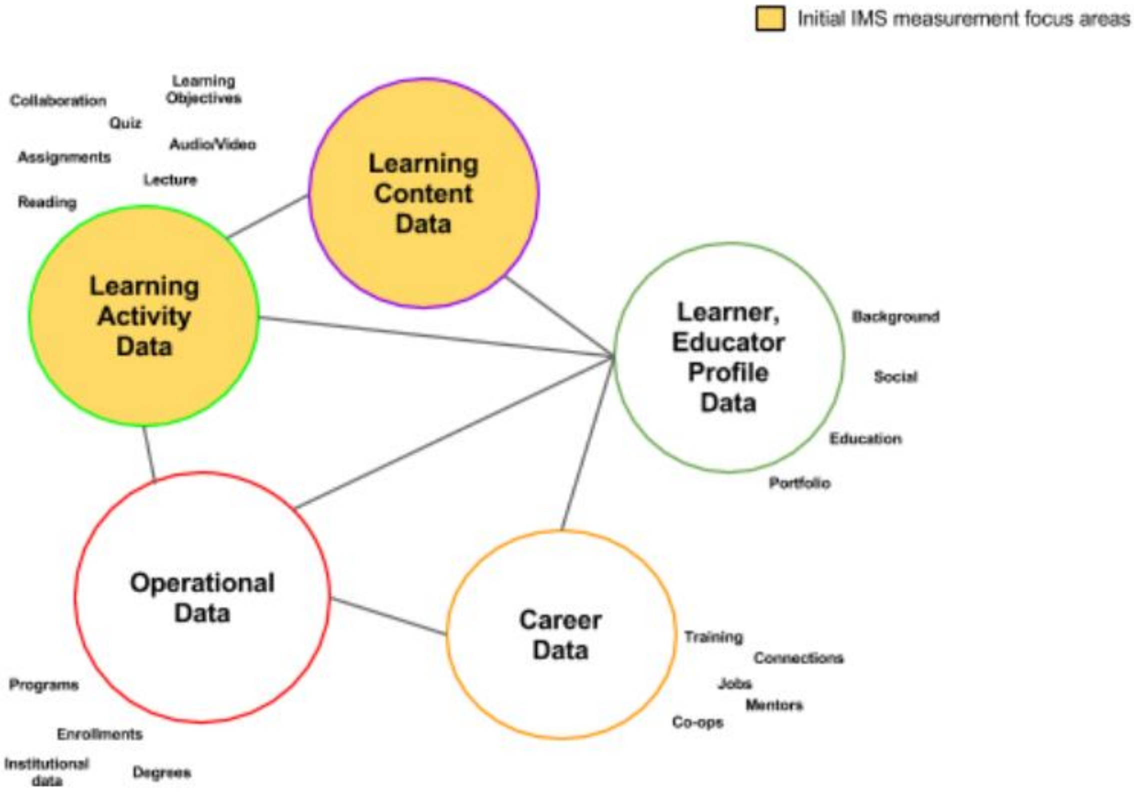

Figure 2: The comprehensive “edu graph” data model. Source: IMS Global Learning Consortium (2013)

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)

3.3.2. 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 3 provides a high level representation of the Caliper environment.

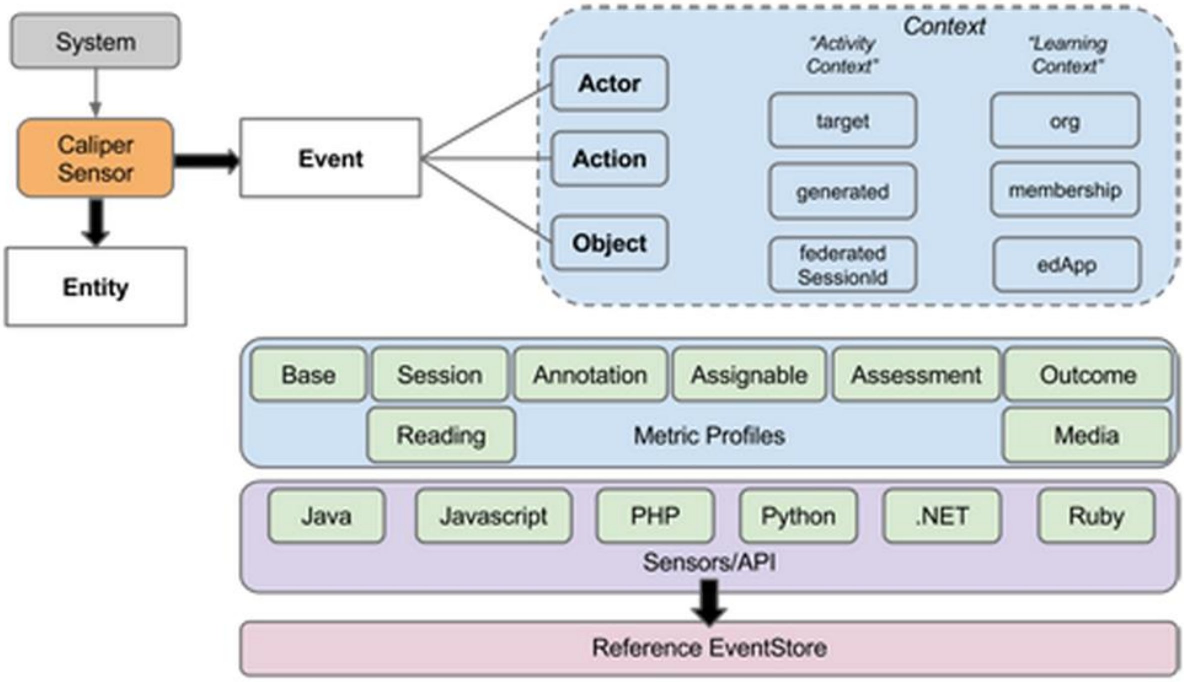

Figure 3: high level representation of the Caliper environment

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 4.

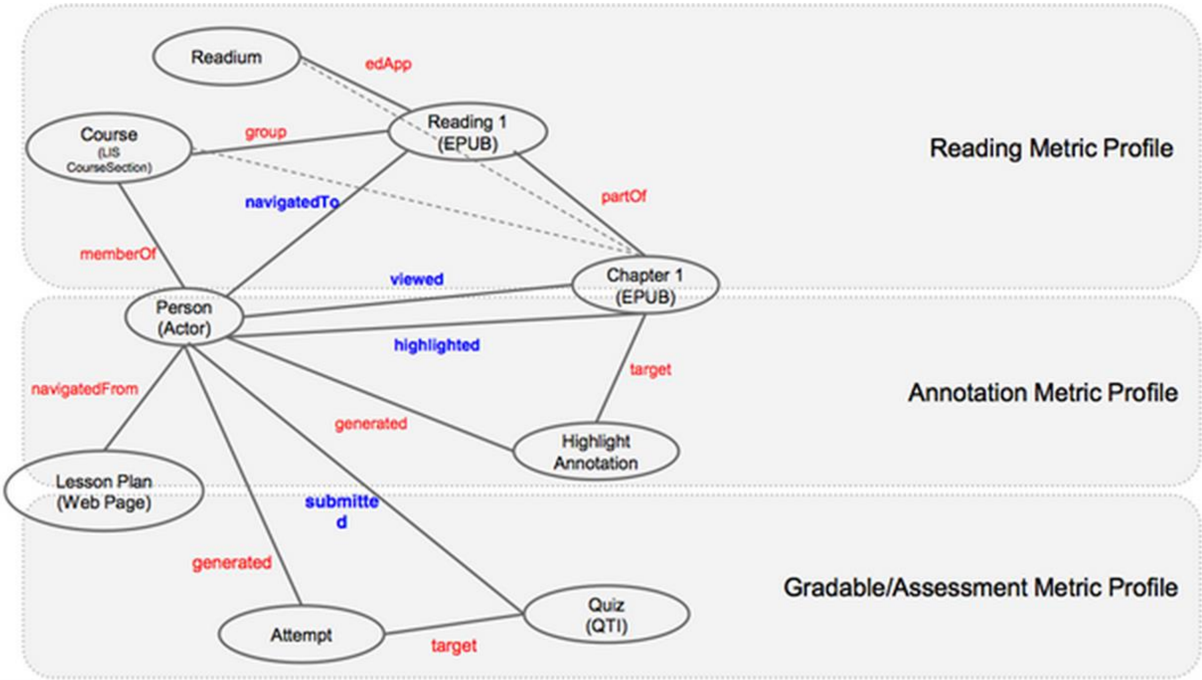

Figure 4: Illustration of Metric Profile Interactions. Source: the Caliper Implementation Guide

3.3.3. Conformance

The third document in the specification is the Conformance Guide, which we discuss in the section on adoption below.

3.4. 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[12] 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,

[12] 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).

4. The current state of development of open architectures for learning analytics

4.1. The context for open architectures for learning analytics

Agreed open specifications enable data to be moved between systems, and so they are the bedrock upon which interoperability is built. But once you start to do this, and to take advantage of the opportunities that are opened up, there are wider implications for the infrastructure which is required. As Kitto said in an interview for this report:

> The problem is you don’t just want xAPI. You have standards and you have legacy infrastructure, and you can do some work with that. But it is not enough. And in Life Long Learning you need to think about the entire datasystem. You need people to take the data with them throughout their education. (Griffiths 2015b)

The management of this data involves a mix of open source and proprietary systems both within and beyond educational systems, and the systems which we normally identify as involving learning analytics form only a small part of this. There have been efforts to bring some structure to this highly varied landscape, involving the designation of boundaries between educational and generic software, the articulation of architectures, and shared development of open source systems for education. Ten years ago Jisc (UK) and DEST (Australia) initiated a major effort to create a Service Oriented Architecture for Higher Education. Its primary goal was “to produce an evolving and sustainable, open standards based service oriented technical framework to support the education and research communities.” (Olivier et al. 2005). Some intensive work was carried out, but no sustainable results were produced. A more sustained effort has been made by the Sakai Foundation. Sakai began in 2004 when a number of US universities started work on synchronizing their assorted learning software to create integrated, open source tools. Their primary goal was to “improve teaching, learning and research by providing a compelling alternative to proprietary learning systems, an innovative platform for learning and collaboration that is produced by and for the higher education community” (Apereo Foundation 2014).

At present Sakai is used by 300 institutions around the world serving more than 4 million students. The Sakai project is now a project of the Apereo Foundation, which has taken on an important role in facilitating the development of an open architecture for LA, in close collaboration with The Society for Learning Analytics Research, Jisc, and a number of leading universities. This is currently the most significant focus of work on open LA architectures. Some other consortia and national agencies are also working on proposals, which relate to a greater or lesser extent to that which is being coordinated by Apereo. There are also initiatives which are less open, or closed, which are worthy of mention although not entirely in scope for this report. In the following section we discuss how these various initiatives interrelate, and outline the architectures that are emerging.

4.2. The Society for Learning Analytics Research

The Society for Learning Analytics Research (SoLAR) is "an inter-disciplinary network of leading international researchers who are exploring the role and impact of analytics on teaching, learning, training and development" (Siemens et al. 2011). While the development of technical infrastructures is not part of SOLAR's mission, it became clear at an early stage that research into the role and impact of analytics was being held back by a lack of infrastructure. In 2011 SOLAR launched the Open Learning Analytics (OLA) project which has provided a point of coordination in the exploration of architectures in LA to the present. The underlying beliefs which informed the project remain relevant as a statement of the rationale for an open learning analytics architecture:

- Openness of process, algorithms, and technologies is important for innovation and meeting the varying contexts of implementation.
- Modularized integration: core analytic tools (or engines) include: adaptation, learning, interventions, and dashboards. The learning analytics platform is an open architecture, enabling researchers to develop their own tools and methods to be integrated with the platform.
- Reduction of inevitable fragmentation by providing an integrated, expandable, open technology that researchers and content producers can use in data mining, analytics, and adaptive content development. Educators, learners, and administrators benefit from modularized functionality: with customizable and extendable core analytics, intervention, and content tools to meet needs of learners and educators (particularly in identifying at-risk students). Administrators benefit from integrated tools that track learning-related activity and then influence resource allocation across multiple tools and spaces of learning. Learners will benefit from having timely and relevant feedback on their performance, as well as content, activity, and social network recommendations to improve and guide their learning (Siemens et al., 2011).

The outline of an architecture was published (see Figure 5). Little progress was made to realising the vision outlined in Siemens et al. (2011). The OLA proposal was an "initial concept paper" (SOLAR 2014), which could not provide a detailed and shared programme of work for those who supported it. Moreover, no funding was obtained to push the work forward. However, the activities of SOLAR, and the LAK conferences which it organises, provide a focal point for the education community in its engagement with analytics, and the OLA project has been important in focusing attention on the need for an open architecture for LA.

In 2014 a summit was held to breathe life into the OLA initiative, including both members of SOLAR and Apereo (see section 4.3 below). Since then members of SOLAR and Apereo have collaborated in a number of events to move forward open learning analytics, which have provided a focus for joint work between learning analytics researchers and the developer community.

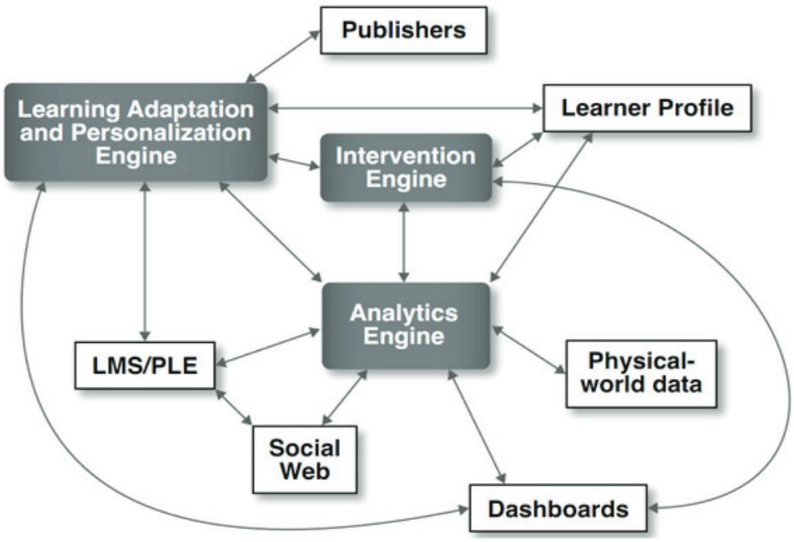

Figure 5: Solar integrated learning analytics system. Source: Siemens et al. (2011)

4.3. The Apereo Learning Analytics Initiative

4.3.1. The Apereo Learning Analytics Initiative in context

Apereo is an open-source foundation formed through the merger of Sakai and Jasig in 2012, The Foundation website states that Apereo is a "non-stock, non-profit corporation, with members drawn from higher education on four continents. Our mission? To help educational organizations deliver their mission, by developing and sustaining open source software" (Apereo Foundation n.d.). In doing this Apereo gives great importance to the incubation process, both in terms of the formal structures of projects and also the development of communities. In an interview for the present report, Alan Berg explained that "Apereo is about building communities and software. It offers a safe area to develop in, and licences that work" (Griffiths 2015a). Given the range of stakeholders involved in LA, Apereo can play an important role in bringing together educationalists and technologists. Berg further comments that

> SOLAR is about setting the framework for learning analytics, and making sure it works pedagogically. It can set out a set of interventions based on pedagogy, and a framework for covering those interventions. The two communities can work together to become an authoritative voice, a combination of reference implementation and scientific framework." (Griffiths 2015a)

The Apereo Learning Analytics Initiative (LAI) "aims to accelerate the operationalization of Learning Analytics software and frameworks, support the validation of analytics pilots across institutions, and work together so as to avoid duplication where possible." (Apereo Foundation 2015). Apereo has had some success in doing this, having achieved the active participation of some leading actors in the LA interoperability world. In addition to the participation of a many universities which are active in the field, (for example Marist Collage, the University of Amsterdam, and the American Public University System), Jisc have joined the Apereo Foundation, and members of SOLAR collaborate closely. The link-up between Jisc, SOLAR and Apereo seems to have been particularly productive, with extensive cross fertilization and convergence of architectures. The Apereo LAI provides systems which can be adapted to any local context, while the Jisc Open Learning Analytics Architecture development can apply some of this work, and contribute its own results back into the wider community.

The Apereo Learning Analytics Community meets every two weeks, shares presentations, and comes to agreements. The whole development process is carried out openly and documented in a Confluence site[13] and on Github[14].

4.3.2. An overview of the Apereo Learning Analytics Initiative

The existing code base of Learning Management Systems and Student Information Systems is, for the foreseeable future, a fact of the educational technology landscape which conditions the infrastructure that can be put in place for learning analytics. On the other hand the purposes to which institutions see for learning analytics varies greatly, generating a wide range of needs. The LAI can be understood as a layer that mediates between these two demands. It constitutes a layer that is coherent with the existing infrastructure, and which offers functionality enabling teachers and learners to build the functionality they need, which can then feed back into the framework and inform its development. To achieve this the LAI is

- Building cards in open dashboards
- Sharing algorithms for predictive models
- Sharing how to get data out of systems.

The creation of this infrastructure will be a significant achievement. However Berg warns that “the real problem is building up knowledge in universities. They want evidence in their local context. You need multidisciplinary teams with power to do heavy lifting” (Griffiths 2015a). In line with the Apereo approach to incubation, the LAI architecture is emergent, guided by the use cases provided by its members, and by those who attend the events which it organises in order to broaden the conversation to a wider range of stakeholders. The architecture is developed through public discussions on the Apereo Confluence site[15]. There is, therefore, no blueprint for the LAI architecture towards which all development is directed, and the information presented here is inevitably a snapshot of the process. Nevertheless, the broad outlines are clear and well established, and seem to be very stable.

Development work within the LAI is coordinated around the development of the LAI Open Learning Analytics Platform, described on (Apereo Foundation 2015) with an update provided at the Open Apereo conference 2015 (Jayaprakash 2015) which is the source for the following figures. The Open Learning Analytics Platform is built on a diamond shaped diagram (Figure 6), which defines four principal areas (‘collection’, ‘storage’, ‘analysis’ and ‘action’) mediated by ‘communication’.

[13] https://confluence.sakaiproject.org/display/LAI/Learning+Analytics+Initiative
[14] https://github.com/Apereo-Learning-Analytics-Initiative
[15] https://confluence.sakaiproject.org/display/LAI/

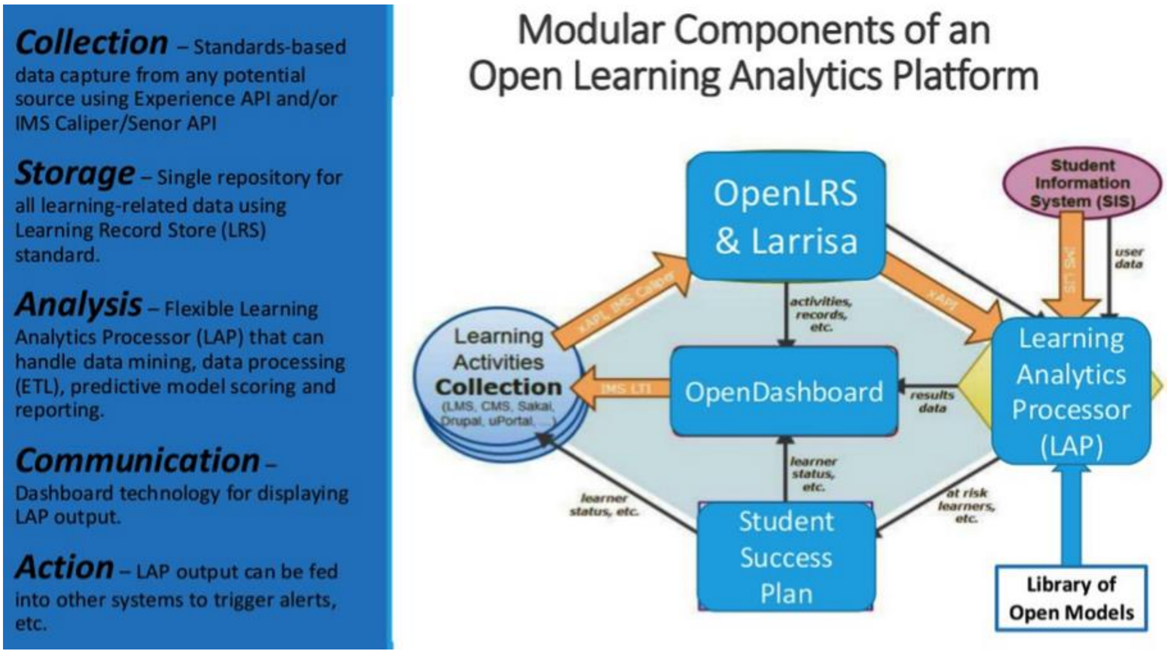

Figure 6: Open Learning Analytics Diamond. Source: Jayaprakash (2015)

It will be noticed that these components have much in common with the Jisc OLAA described in the next section. The components are connected by means of interoperability specifications. At present xAPI is used to channel interactions from learning systems to the learning store, but it is planned to also include IMS Caliper. LTI is used to deliver the Open Dashboard. Open APIs are being developed to link the other components.

Figure 7 shows how the components of the Open Learning Analytics Platform are being addressed through a number of Apereo development projects.

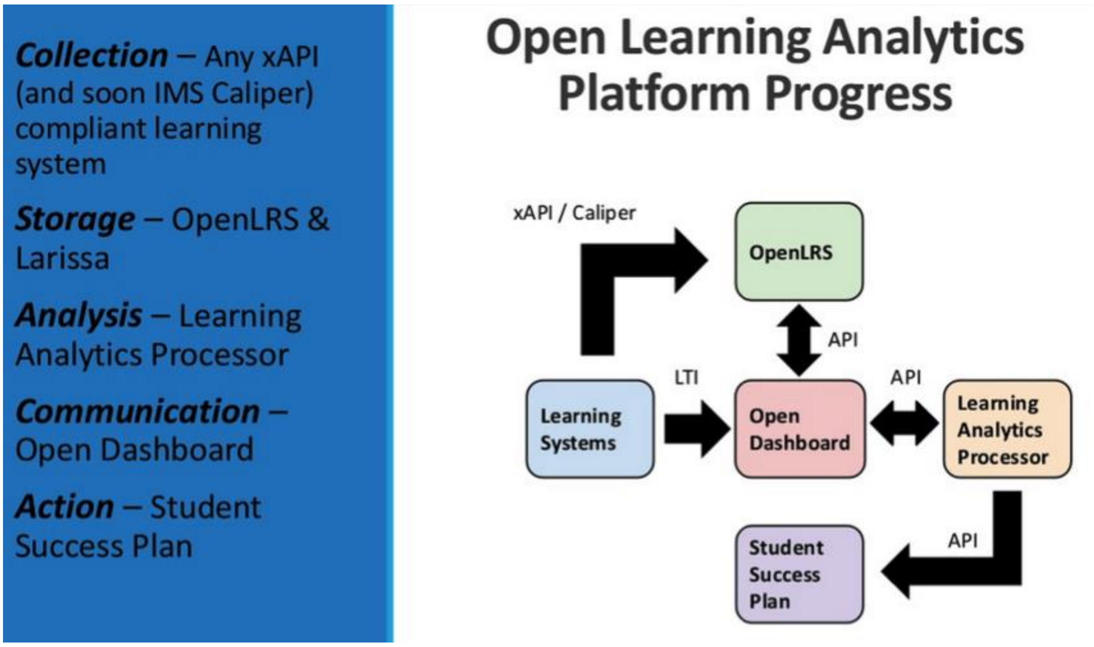

Figure 7: Open Learning Analytics Platform Progress. Source: Jayaprakash (2015)

Taking these in turn, the development work being carried out by the Apereo Foundation includes:

Collection: Any xAPI (and soon Caliper) conformant system can perform the collection function, but Apereo also provides xAPI integration in the Sakai Collaboration and Learning Environment, the Apereo Open Academic Environment, and uPortal.

Storage: OpenLRS is an open source Java based Learning Record Store which is compatible with xAPI. The project entered incubation in June 2015. The alternative Larissa aims is to provide a locally deployable LRS that can scale up to very heavy loads.

Analysis: The Learning Analytics Processor project is aimed at accelerating the future of predictive learning analytics through the development of a flexible and highly scalable tool that will facilitate everything from academic early alert systems to data visualizations. Along with this powerful "big data" tool will come a library of open predictive models which can be shared across higher education free of licensing costs and, most importantly, allow institutions to collaborate on enhancing and improving these models over time. The project entered incubation in June 2015[16].

Communication: OpenDashboard is a Java web application that provides a framework for displaying visualizations and data views called "cards". Cards represent a single discrete visualization or data view but share an API and data model. Cards are stored in a card library. The project entered incubation in June 2015. Unicon has been contracted to make the open dashboard as scalable as possible, and the roadmap for Apereo envisages a link-up to Hadoop to enable it to scale further. OpenDashboard is IMS Learning Tools Interoperability compliant, facilitating its integration with other systems[17].

Action: Student Success Plan supports a coaching and counselling model, and expedites interventions for students in need (Jisc, Sinclair Community College, and Unicon). It includes case management, academic advising tools, early alert, integration with student information systems, and reporting and data collection tools[18].

Feeding into the Learning Analytics Platform is a Library of Open Models. This builds on the Open Academic Analytics Initiative, whose Early Alert System is the first model to be deployed (see Figure 8).

[16] See https://confluence.sakaiproject.org/display/LAI/Apereo+Learning+Analytics+Processor for more details.
[17] See https://confluence.sakaiproject.org/display/LAI/OpenLRS+and+OpenDashboard for more details.
[18] See http://www.studentsuccessplan.org/features/my-academic-plan for more details.

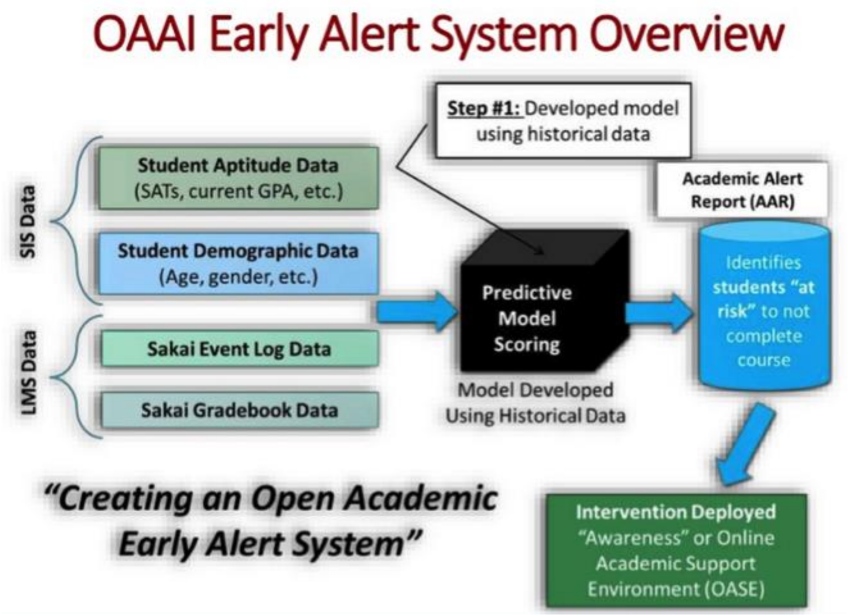

Figure 8: OAAI Early Alert System Overview. Source: Jayaprakash (2015)

The model is a collection of algorithms that have been tried and are exportable in PMML. The algorithms can be trained, and used in local context, and this has been done for Jisc as part of the Apereo reference implementation. The library of open models will increase and better solutions found.

In addition to the specifications mentioned above which are already part of the Apereo Open Learning Analytics architecture, the roadmap also includes support for IMS Caliper and LTI 2.

4.4. The Jisc Open Learning Analytics Architecture in context

4.4.1. The Jisc Open Learning Analytics Architecture in context.

Jisc is a not-for-profit organisation which is dedicated entirely to the UK HE sectors' individual and collective needs (Jisc n.d.). Over 80% of Jisc funding comes from UK higher education and further education funding bodies, but the organisation will in future be required to sell its services directly to institutions. One of the principal current projects being undertaken by Jisc is Effective Learning Analytics, which is developing the Open Learning Analytics Architecture (OLAA). It is interesting that at a time when Jisc needs to demonstrate its value to the higher education sector it has chosen the development of an architecture for learning analytics as one of the means that can achieve this.

As stated by Phil Richards, Chief Innovation Officer for Jisc, the definition of LA adopted in the OLAA is "the application of big data techniques such as machine based learning and data mining to help learners and institutions meet their goals" (Richards 2015). This is substantially wider than "The use of analytic techniques to … support the achievement of specific learning goals" proposed by Educause (Van Barneveld et al. 2012). This difference in terminology may not lead to differences in the learning analytics methods deployed, but it does suggest the breadth of Jisc's scope, and its intention to interoperate with a wide range of existing institutional systems, both open source and proprietary.

Jisc staff have developed an architecture, drawing extensively on the SOLAR OLA initiative, and have procured the development of a number of components to create a basic learning analytics system. Perhaps following the lead of Apereo, Jisc have taken the decision to base their architecture on other work which is underway. Jisc's architecture also has much in common with the Apereo Open Analytics architecture, as the strong presence of Unicon and Marist College suggests. This relationship has been facilitated by the strong presence of Apereo in the University of Amsterdam, and the long standing links between Jisc and SURF (which has a somewhat similar role in Holland). Jisc have now formalised this relationship by becoming members of Apereo.

The procured systems include bespoke versions of proprietary products (e.g. Tribal) and adaptations of open source systems (e.g. Learning Locker). The resulting system will be deployed as the Jisc Learning Analytics Service, which will be made available to UK colleges and universities, providing information about student engagement and achievement, and alerts on students who are at risk.

As described by Sclater (2015a): "The service will consist of the following components, and institutions will be able opt in to use some or all the components as required:

- **A learning analytics processor** – a tool to provide predictions on student success and other analytics on learning data to feed into student intervention systems.
- **A staff dashboard** – a presentation layer to be used by staff in institutions to view learning analytics on students. Initially this presentation layer will be focussed on the learner but dashboards for managers, librarians and IT managers could also be developed.
- **An alert and intervention system** – a tool to provide alerts to staff and students and to allow them to manage intervention activity. The system will also be able to provide data such as methods and success, to be fed into an exemplar "cookbook" on learning analytics.
- **A student app** – based on requirements gathering with staff and students. Integration with existing institutional apps will be supported."

The resulting system will be cloud hosted, with Jisc providing hosted solutions for each of the components. All data is held in the EU, using mainstream cloud services provided (either by Amazon AWS or Rackspace). A complete set of the open source components will be made available for local installations if cloud hosting is problematic for any reason. The source for the following overview of the Jisc OLAA is the material available on Jisc's Moodle site (Jisc n.d.), except where otherwise stated.

4.4.2. Overview of the Jisc Open Learning Analytics Architecture

The Jisc Learning Analytics service architecture has three layers (Figure 9):

- The **Presentation and Action layer** provides dashboards, a student app, and tools for managing student interventions.
- The **Data Storage and Analysis Layer** deals with storing the data that is collected, analysing it, passing it on to the presentation layer in a suitable form.
- The **Data Collection layer** collects data about student activity from the student record system via xAPI, against a standard data model.

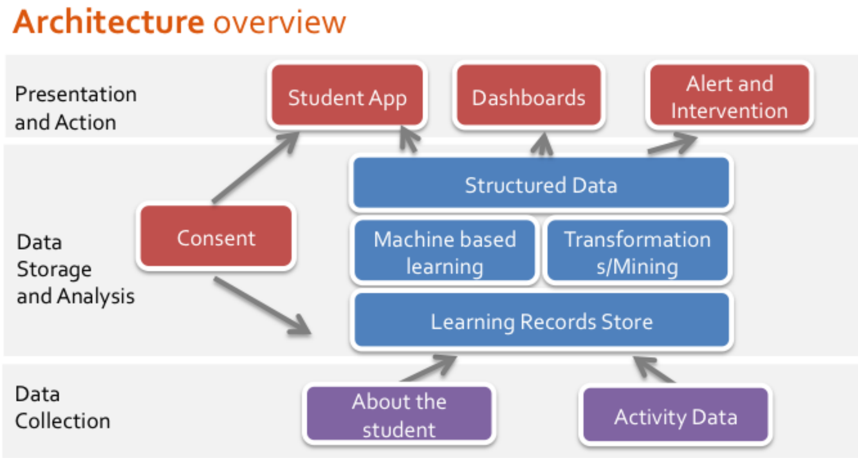

Figure 9: Overview of the Jisc Open Learning Analytics Architecture. Source: Jisc (n.d.)

RESTful APIs are used to interchange data in JSON format between the layers. The APIs of each component are published so that institutions and third party vendors can build additional services on top of the architecture. We now look at each of the layers in turn, working from the bottom up.

5.4.2.1 Data collection layer

Two kinds of data are collected:

Activity data: what a student does. This is captured using xAPI, and Jisc provide a plugin for the purpose for both Moodle and Blackboard. Plugins are also being developed to capture attendance and library access data.

Personal Data: who a student is, and what courses they are studying. This will typically be extracted from the student record system, and transformed into the standard Jisc Analytics data model. An overview of the data model is provided in Figure 10. The information held about students is structured according to UK conventions, and so the model makes use of concepts and definitions from UK agencies, including HESA and ILR. Nevertheless, we do not believe that it will appear strange to educationalists from other countries.

An alpha version of the Unified Data Definitions to be used in gathering data has been published[19], and the overall data structure is shown in Figure 10 below. Again, much will be familiar in other countries, but the details (at least) will vary. For example, it seems likely that the inclusion data related to ethnicity, socio-economic status, parents educational level, and disability, relates as much to UK government policy and monitoring as it does to strictly learning analytics issues. xAPI profiles are used to ensure that student activity on different systems (e.g. Moodle and Blackboard) is captured in the same way. This is also a top priority for the Data Interoperability Standards Consortium (DISC) recently established to steward xAPI. Such profiles can also act as means of relating the differing data structures in institutional and national implementations to standard analytics algorithms.

[19] https://courses.alpha.jisc.ac.uk/moodle/course/view.php?id=14

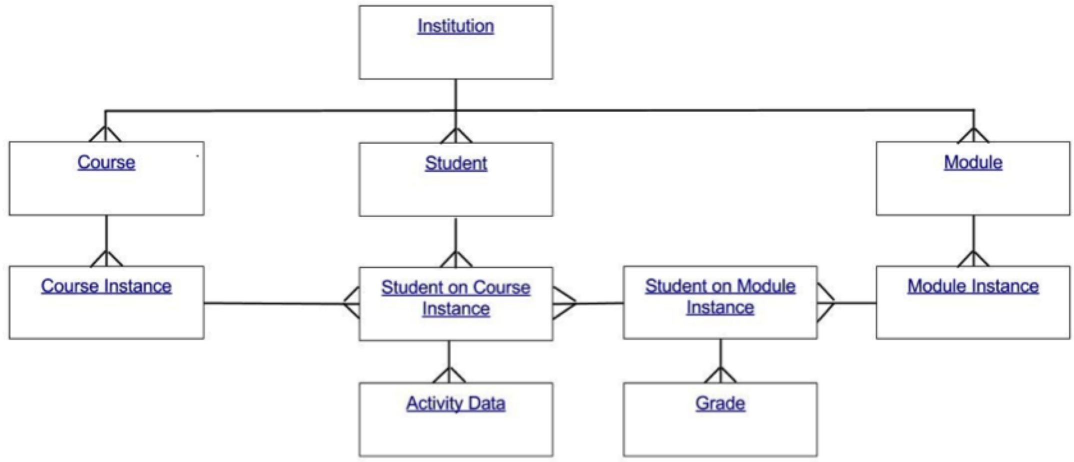

Figure 10: Jisc OLAA overall data structure. Source: Jisc (n.d.)

Data Storage and Analysis layer

The structure of the Data Storage and Analysis layer is shown in Figure 11.

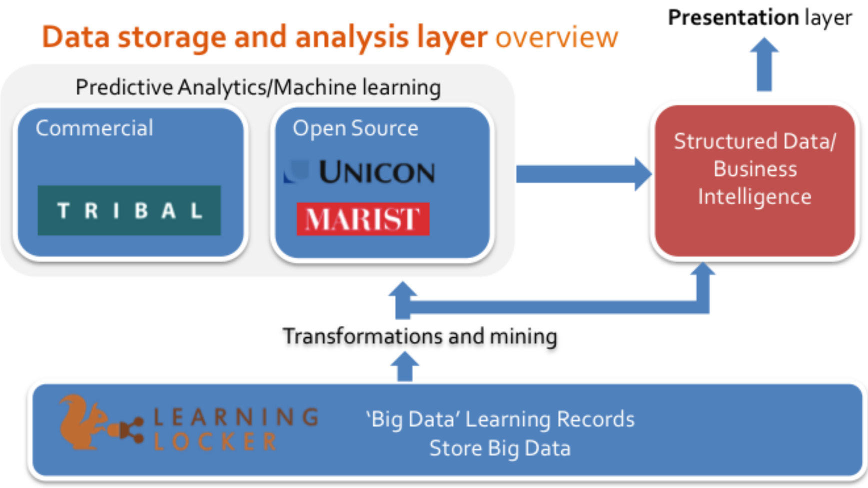

Figure 11: Jisc OLAA data storage and analysis layer. Source: Jisc (n.d.)

The data gathered in the data collection layer is stored in a Learning Record Store. The primary data storage tool is Learning Locker, which is an open source system licensed under GPL 3.0, and focussed specifically on storing xAPI data. Learning Locker is developed by HT2, and is hosted in the UK by Rackspace (although it can also be locally hosted). Learning Locker takes data from learning systems in xAPI format, and stores it in a NoSQL database[20]. The Student Success Plan module should be available from the first quarter of 2016. The institution will choose which system to deploy, depending on whether they already have something in place to handle interventions.

Learning Locker provides APIs to allow other systems to interrogate the data, including dashboards, apps and predictive modelling tools. In the Jisc OLAA the data is typically passed on to a predictive analytics engine, and adopters have a choice of two. Learning Analytics Process (LAP) is an open source solution, based on the Weka open source machine learning engine, while Tribal Insight is an

[20] For more information see http://learninglocker.net/ and http://ht2.co.uk.

integrated suite, including dashboards as well as the predictive engine. LAP is provided by Jisc as a multi-tenanted solution, hosted in the UK on Amazon AWS, and is also available as a standalone download. Tribal Insight is only available as a hosted solution through the Jisc service.

Presentation and Action layer

As shown in Figure 9, the Presentation and Action layer of the Jisc OLAA is composed of a student app, dashboards and alert and intervention. The **student app** is being developed for the Jisc OLAA by Therapy Box. This enables students to engage with the data held about them, and to provide their own 'self declared' data. As Sclater (2015c) describes, it will include

- activity feed or timeline, with a historical view of the activities of students and their peers
- engagement and attainment overview, which provides an overview of academic performance, and in particular how the student compares to others
- activity comparison graph of engagement over time and how it compares with others students
- interface for inputting 'self-declared' study activities and targets.

Dashboards provide visual tools for lecturers, module leaders, senior staff and support staff to see representations of student engagement, cohort comparisons, etc., while **Alert and Intervention** functionality provides actionable recommendations. Institutions have three different options for deploying dashboards: a commercial solution, provided by Tribal, an open source solution provided by Unicon/Marist, or by integrating data into their own business intelligence service such as Tableau. The systems provided by both Tribal and Unicon/Marist span the analysis and presentation and action layers.

Jisc's Learning Analytics Services will offer a customised version of **Tribal's Student Insight**. This is a cloud hosted application, which has functionality in both the storage and analysis layer and the presentation and action layer (Figure 12). As explained in Sclater (2014b),

> Tribal use the data in SITS, and from other sources such as the institutional learning management system and the library, to build a model of engagement, with a focus on the risk of student drop-out or module failure. Tribal are developing a standard set of models that can be customised and optimised for an individual institution. The dashboard is delivered with HTML5. Student Insight also integrates with the Tribal Enterprise Service Desk, which manages student support processes, and this can be used to manage interventions following on from the results of analytics. A very large proportion of UK higher and further education institutions have Tribal's Student Information System installed, and so integration with this system is an attractive proposition for many universities and colleges.

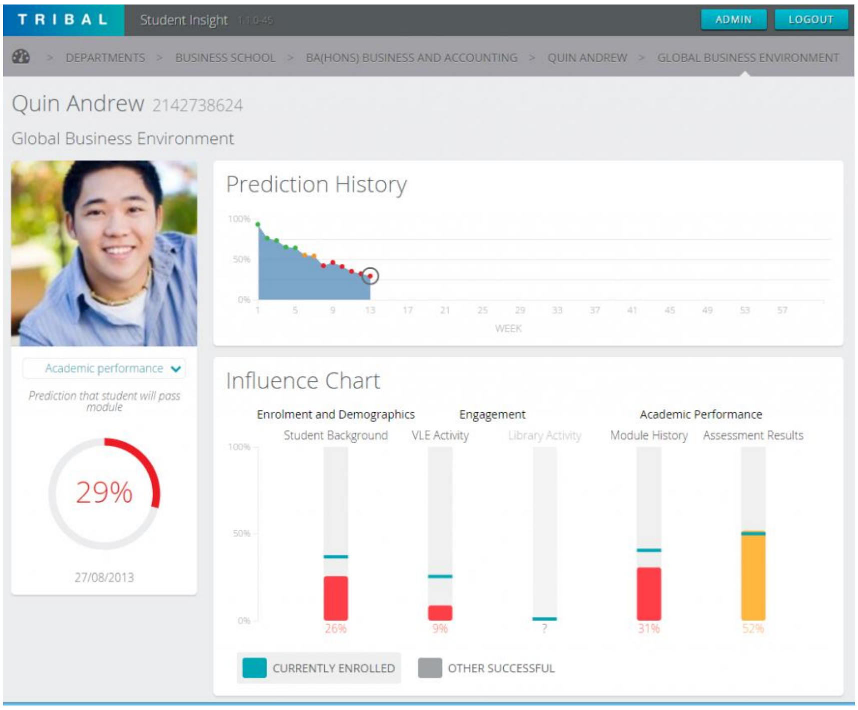

Figure 12: Tribal Student Insight. Source: Jisc (n.d.)

The **Student Success Plan** (SSP) tool is based on open source tools developed by Unicon in collaboration with Marist College in New York State, and incubated in the Apereo Foundation. The functionality of the SSP (Figure 13) has been customised to meet the needs of the UK market. The contribution of Marist College is centred on the Predictive Analytics Reporting Framework[21] (see section 4.7).

Figure 13: Student Success Plan. Source: Jisc (n.d.)

[21] For detailed information on SSP see http://www.studentsuccessplan.org/

4.5. Unizin

Another organisation that might have an impact on LA interoperability is Unizin. This is an invitation-only organisation, which does not provide public details of its strategy and development. However, presentations by the consortium show the broad outlines. A presentation at the EUNIS conference in 2015 stressed the importance of standards: "Unizin is predicated on using standards to drive innovation and efficiency for scalable delivery across the digital learning ecosystem", and indicated that Caliper would be a key component of this system (Maas & Qasi 2015). The principal goals of Unizin (Glover 2015) are to:

- Acquire a common LMS
- Acquire or create a repository for digital learning objects
- Acquire/create/develop Learning Analytics.

In line with these goals, the consortium is adopting Canvas as a common Learning Management System, and has purchased Courseload, an 'E-Textbook and Digital Course Materials Solution'[22]. As yet little information is available about plans for learning analytics, but a recent post the Inside Higher Ed site reports on an interview with Unizin COO Robin Littleworth

> Unizin's first major features are two "relays" -- one for content, the other for analytics. Details about the relays are still scarce. The content relay is more or less a search engine that would enable faculty members to quickly search repositories for learning objects and plug them into their courses, Littleworth said, while the analytics relay would collect information about how content, apps and platforms are used. (Straumsheim 2015)

Feldstein comments that "What is remarkable is the level of secrecy surrounding the project" (Feldstein 2014), and given the lack of publicly available information, it is hard to assess the impact that the Unizin will have on LA interoperability. If successful, the initiative will be a very large scale learning analytics deployment making use of standards-based systems. As Figure 14 indicates, Caliper will be an important part of this, and engagement with IMS is likely to be significant.

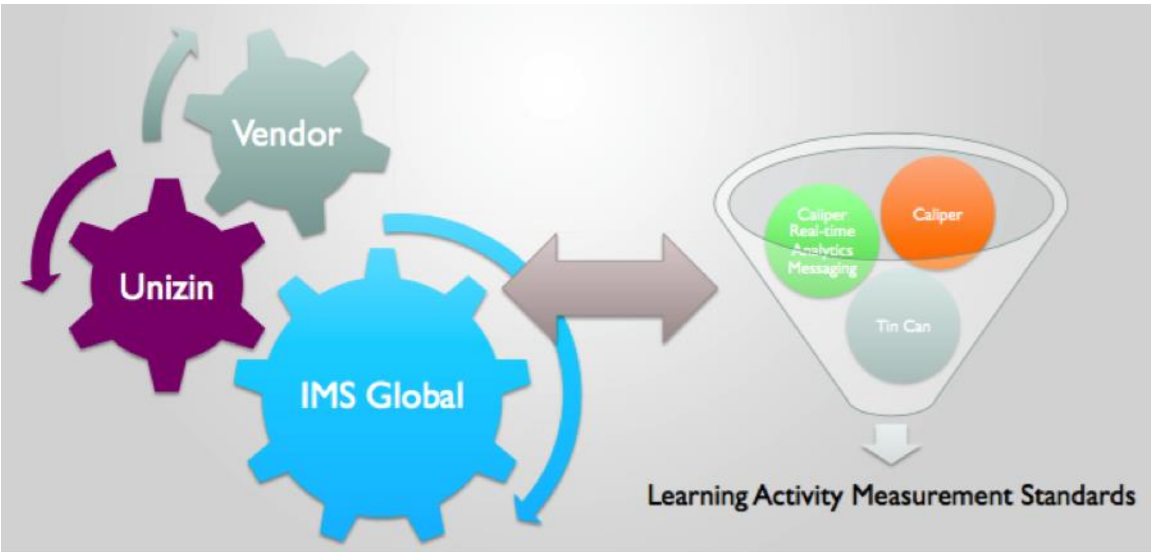

Figure 14: Unizin Learning Activity Measurement Standards. Source: Maas & Qasi (2015)

[22] www.courseload.com

On November 3rd, 2015 Unizin announced that the consortium partners with IMS Global Learning Consortium "to drive Caliper Analytics adoption". "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." (Raths 2015)

4.6. The Predictive Analytics Reporting Framework

The Predictive Analytics Reporting (PAR) Framework describes itself as "a non-profit provider of analytics-as-a-service" with more than 351 member campuses (PAR Framework n.d.). The aspect of this work which is relevant to our present concerns is the development and maintenance by PAR of common data definitions. PAR has "a scalable multi-institutional database that yields … common, cross-institutional metrics for accountability that consider student outcomes" (PAR Framework n.d.) The database includes 2 million de-identified student records and more than 20 million course level records. The scale of this corpus makes it possible to look for patterns of student success and failure, and to propose cross institutional benchmarks. These benchmarks are valuable in training algorithms for deployment in local contexts.

This cross institutional data gathering is only possible with a standard set of data definitions, which have been developed and maintained by PAR. There is no expectation "that institutions will change all their variables to match PAR's data dictionary. Rather, the PAR Framework is created as a way to map what is in your system with what is in my system, so that we can communicate better through this common language (Grush 2013). PAR have also developed a Student Success Matrix which provides a common structure "to inventory, organize, and conceptualize supports aimed at improving student outcomes" (PAR Framework n.d.)[23]. Both the PAR data definitions have been published under a Creative Commons license[24]. The PAR framework has been adopted by the Apereo foundation for use in the Student Success Plan, which is also a component of the Jisc Open Learning Analytics Architecture. Lauría et al. (2013) report that

> Predictive models were trained and tested using Marist College data, and those models were then applied on pilot runs using data from several partner institutions. The research tested the portability of those models, and the success of intervention strategies in improving "at Risk" student outcomes. The results are promising as they seem to point at a higher portability of those models than initially anticipated. (Lauría et al. 2013)

In a later publication the authors note that an open research question is

> *How portable are predictive models designed for one type of course delivery (e.g., face-to-face) when they are deployed in another delivery format (e.g., fully online)?* We are particularly interested in exploring the issue of portability regarding face-to-face and fully online programs given how much more LMS usage takes place in the latter mode of instruction. It may be that models developed based on face-to-face courses do not import well to fully online courses or at least that such models could be significantly improved if they were customized for fully online courses. (Jayaprakash et al. 2014) italics in the original.

[23] See also https://community.datacookbook.com/public/institutions/par
[24] Available at https://community.datacookbook.com/public/institutions/par

One might add that in addition to institutional factors, it is also an open question how well these predictive models will work in different socio-economic, cultural and linguistic contexts.

4.7. UvAinform (University of Amsterdam)

The University of Amsterdam initiated the UvAInform project in 2013 (Mol & Kismihók 2014) in order to develop an informed strategy regarding the development and implementation of university wide learning analytics services. The project has evolved from taking a centralised approach to the development and implementation of these services to a more devolved approach, in which seven different pilots are being carried out across the various faculties of the University, so as to gain experiences, learn valuable lessons, and develop expertise with regard to a university wide learning analytics program (Figure 15). Furthermore, the project initiated the development of OpenLRS (Larissa), an open source Learning Record Store for collecting student activity[25]. Berg comments "There wasn't a scalable LRS, so we built one. It works, it scales, but there is a debate about resources. Is there resource for incubation? OpenLRS Unicon is the alternative. Larissa has better parsing. OpenLRS has a more scalable back end." (Griffiths 2015a). In combination with a data warehouse and an open source Extract Transform and Load layer, Kettle[26], the aim is to unlock the large number of data silos within the University, many of which were never developed specifically for LA purposes.

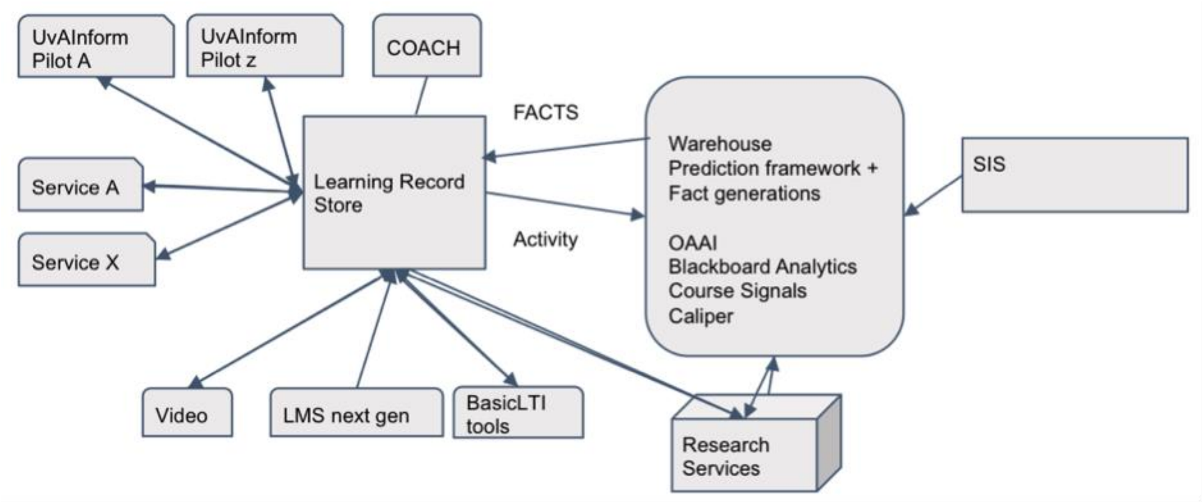

Figure 15: University of Amsterdam Learning Analytics Framework. Courtesy of Alan Berg

4.8. IMS Global Inc. Architecture

Much of the architectural work by Apereo and Jisc above is conditioned by the structure and use cases of the xAPI specification. The situation for IMS Caliper is somewhat different, in part because metric profiles in IMS are more prescriptive than the equivalent structures in xAPI, and in part because the structure of IMS as a closed group primarily composed of vendors means that there is no need to coordinate a distributed development process. Nevertheless it has been for some years an ambition of IMS to have an influence on the architecture of educational systems. Abel et al. (2013) set out a call for action for 'A New Architecture for Learning', without making a concrete

[25] Available at https://github.com/Apereo-Learning-Analytics-Initiative/Larissa
[26] Available at https://github.com/pentaho/pentaho-kettle/

proposal. In any event, it is clearly the case that if IMS specifications are to be used extensively, then they must correspond to the data pathways used by the systems deployed in education. One may, however, wonder if the commercial imperatives vendors of existing systems (who have a strong presence in IMS) are compatible with radical restructuring of the environment in which vendors operate, or they would be receptive to calls for factoring out functionality from monolithic applications. If this were the case, then one would expect an IMS architecture to be largely descriptive of current practice. The way in which IMS conceives the relationship of its specifications to educational systems is shown in Figure 16.

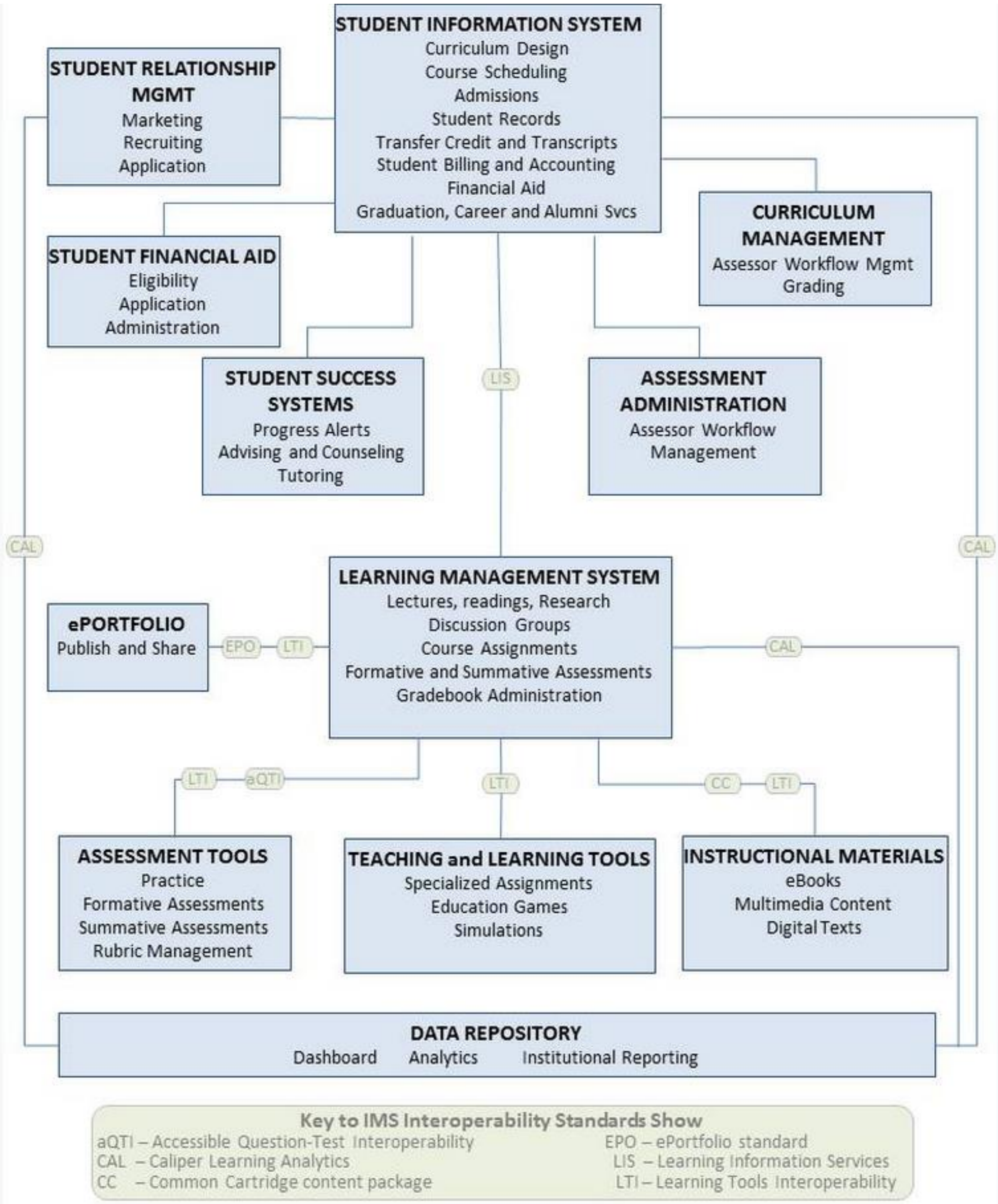

Figure 16: Reference Educational Enterprise Architecture with IMS Global integration points. Source: IMS Global (n.d.)

4.9. The ISO Learning Analytics Interoperability Reference Model

The International Standards Organisation (ISO) is an independent, non-governmental international organization, which has 162 national standards bodies as members. ISO/IEC JTC 1/SC36 is the committee of ISO which deals with Information technology for learning, education and training. In 2015 this committee started a new workgroup on LA; and their first project was a reference model for LA Interoperability. The first draft defined the core parts of an LA workflow as Data Collection, Data Storing and Processing, Analysis, and Visualisation, as shown in Figure 17. However, community exchange organised by LACE, among others, had shown that what happens prior to “bringing data together from one or more points for use in a computer” (the definition used in ISO/IEC 2382-31 of 1997 for Data Collection) is crucial for LA.

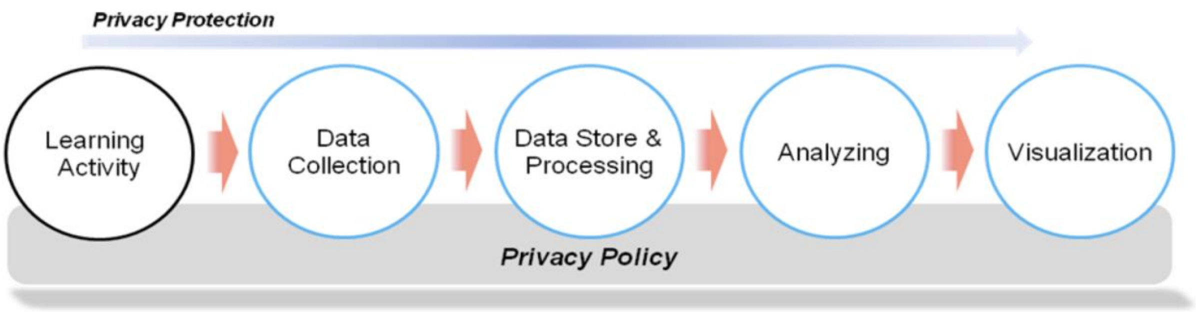

Figure 17: Abstract Workflow of Learning Analytics, from 2nd draft of a standard under development by ISO/IEC JTC 1/SC36 (N3182)

In the second version of the workflow diagram the SC36/WG8 project editors added the Learning Activity process and included Privacy Policy and Privacy Protection as contexts for the whole workflow. Whether this will be included in the final standard remains to be seen. The point here is simply to argue that technical architectures are derived from abstract models created by domain experts in an on-going dialogue. If there is no abstract concept for a process there will be no tool. The Working Group is still at an early stage of its activity, and the introduction of Privacy Protection and Privacy Policy to the model might have significance for further design.

Mapping interoperability activities and designs to the model in Figure 17 we observe that most of the activities have been focussed on Learning Activity. Data Collection and Data Storage & Processing are addressed, but it is not clear how much current work within the LA communities of practice has influenced the development. For example, Learning Record Store (LRS) is a widely used concept that is part of data collection and storage; however, it is not clear to which degree the privacy issues identified above have been part of the development of LRS systems. Analysis and Visualisation have both interoperability challenges. However, these have not been very high on the agenda for the LA community as it seems to be taken for granted that the wider field of analytics will take care of these issues.

The ISO/IEC JTC 1/SC36 working group on learning analytics (WG8) has come up with a draft for a technical report on «Learning Analytics Interoperability – Part 1: Reference model». The first voting on the draft is end of November 2015, and the final report is expected to be published in 2016. WG8 has also initiated a study group focussing on «Systems governance for learning analytics» and «Data framework for learning analytics interoperability». The task of the group is within summer 2016 to have come up with a rationale and scope for new work items.

The LA Interoperability standard is planned as a multipart standard, with a reference model as part 1, and system requirements as a second part, both derived from the use cases originally gathered from the national standard bodies. A rationale for developing a third part on “Guidelines for Data Interoperability” is also being drafted. This part will look into use cases of creating interoperability between IMS Caliper profiles and Experience API profiles.

The ISO working group on learning analytics, WG8 of ISO/IEC JTC 1/SC36, was kicked off in June 2015 after more than a year of preparations in a so-called Ad Hoc group. The Ad Hoc group had been busy gathering use cases for the national bodies all over the world, and the first draft of a technical report of a reference model for LA Interoperability was based on these use cases abstracting them into a reference architecture. However, the problem with this development process is twofold: First, national bodies are slow to respond to calls for use cases, and the result will never be complete. Second, after a first round of requirement gathering the process tends to stall and continue as a word-smithing exercise among working group experts, with little guarantee that important new requirements are included. (In the case of the current draft reference model, it was the intervention of LACE project input through a Norwegian expert that led to inclusion of Privacy Policy as a vital workflow process, see Figure 18.) Consequently, ISO work (at least in the context of the sub committee dealing with standards for learning, education and training, SC36), tends to be slow moving, high level and prone to produce abstract designs of models that suffer from an uneasy disconnect from real world practice. It is too early to say if the current work will fall into this trap.

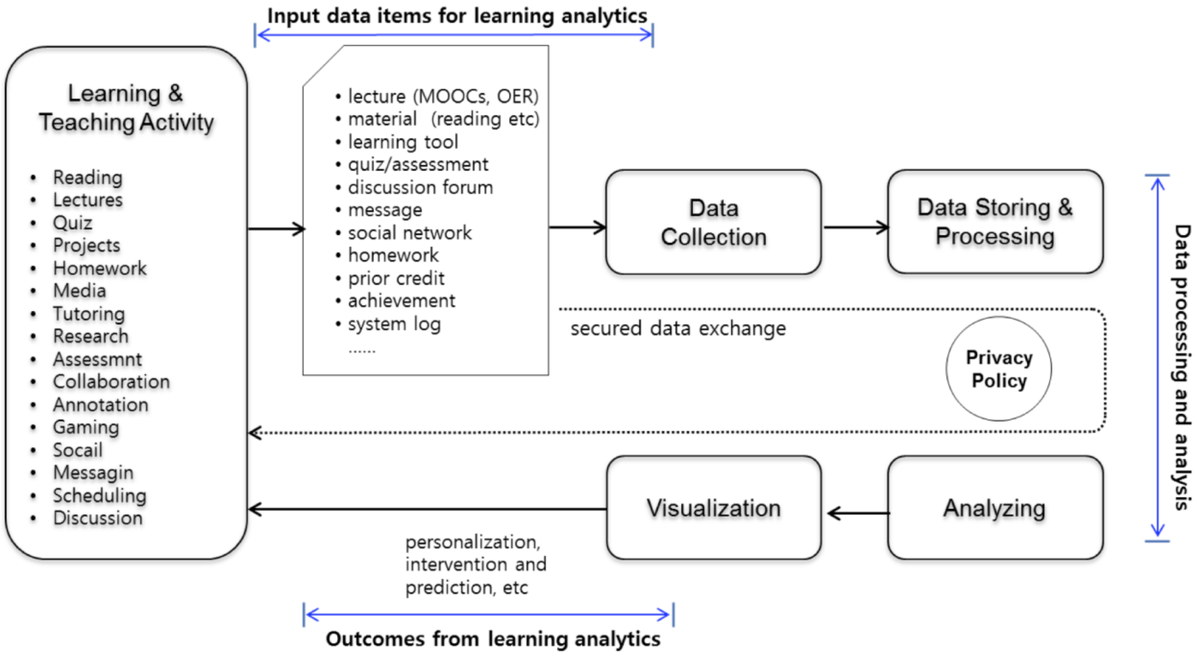

Figure 18: Workflow of Learning Analytics, from ISO/IEC JTC 1/SC36 N3182

4.10. Systems for ensuring data privacy

Data privacy raises many ethical issues which are not within the scope of this report. But data privacy also raises pressing technological issues which are relevant to interoperability. Sclater reports on a 2015 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 students would not be prepared to use a learning analytics system unless the data was gathered anonymously. Once learners had gained confidence with the system they might be persuaded to opt in to receive better feedback. Thus the consent service was confirmed by the group as a critical part of the architecture. (Sclater 2015b)

He also comments that the student consent platform is likely to be one of the most complex elements of the Apereo architecture.

The recent ruling on Safe Harbour by the European Court of Justice is also relevant to this issue. As the BBC summarised

> Personal data should no longer be transferred to US bodies solely on the basis they are Safe Harbour-certified. Instead to authorise the "export" of the data, the two bodies involved must draw up and sign what's referred to as "model contract clauses", which set out the US organisation's privacy obligations. (European Court of Justice 2015)

The practical details of this process are still unclear, but it will, at least complicate the use of cloud-based software in LA. Even the support of software from the USA can be problematic, as remote access will often involve visualising personal data, i.e. data transfer. Consequently a need may emerge for a more flexible deployment of data storage services, which can be operated at institutional, national or European levels, policy requires.

4.10.1. MIT Open Personal Data Store / Safe Answers (OpenPDS/SA)

As we have discussed in section 3.2, the architecture for xAPI includes a Learning Record Store to store an individual's personal learning data, and the architecture IMS Caliper has a similar component (see figure 3 above). This functionality raises substantial questions about privacy and access. However, these questions are much wider in scope than LA, both in technical and social terms, and so it is understandable that neither xAPI nor Caliper include them within their remit. The Open Personal Data Store (PDS) under development at MIT is a development with a wider scope which is intended to solve these (and other) privacy issues. OpenPDS is not an educational application, but rather a proposed solution to a wider problem of data security that can be summarised as "it will be extremely difficult to anonymize high-dimensional data such as geolocation while retaining the value of the data" (OPENPDS/A n.d.).

The system (Figure 19) seeks to make two contributions.

1. "...openPDS, a personal metadata management framework that allows individuals to collect, store, and give fine-grained access to their metadata to third parties ...
2. SafeAnswers, a new and practical way of protecting the privacy of metadata at an individual level. … SafeAnswers turns a hard anonymization problem into a more tractable security one. It allows services to ask questions whose answers are calculated against the metadata instead of trying to anonymize individuals' metadata." (de Montjoye et al. 2014).

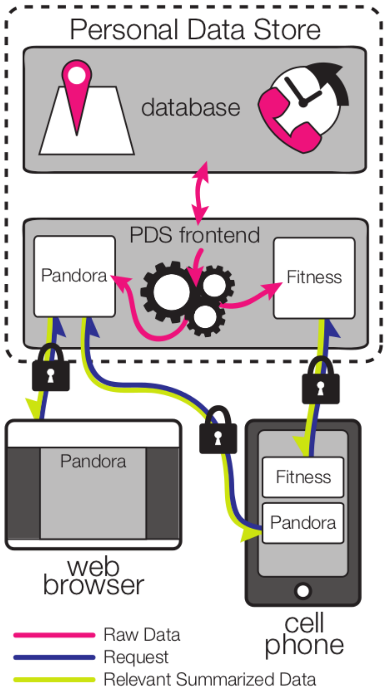

Figure 19: The Personal Data Store architecture. Source: de Montjoye et al. (2015)

This functionality, on the face of it, looks a potential match for the privacy requirements of LA. The PDS is not related to the Apereo Open Learning Analytics initiative at the moment, when asked about this in a LACE interview (Griffiths 2015a) Berg said that this was an open possibility. He stressed however, that there is a need to balance the technical aspects with the legal requirements. Berg argues that a persuasive case can be made for establishing an escrow agency that can guarantee a set of analytics services to individuals, and determine who could look at the data. This could scale up to continental level, and this would be advantageous in Europe, where part of the legal framework is established at a European level.

A prototype application OpenPDS/SA has been developed by the team at MIT, and the current code is available on Github[27]. It remains to be seen if this technology will gain traction in the internet as a whole, or in the LA community. The Jisc approach at present is to hold data 'securely in the cloud, using UK based providers - either Amazon or Rackspace', but it is not clear at this stage if this solution will be sufficient as privacy demands develop. For the moment a watching brief is to be recommended, as Open PDS offers, at least, an interesting possible response to the privacy problems faced by the Apereo and Jisc architectures identified in (Sclater, Berg and Webb. 2015).

4.10.2. Kennisnet and the Education & ICT Breakthrough project

Kennisnet[28] is the public organisation for education and ICT in the Netherlands. As described by Van Bruggen in the LACE Evidence Hub, Kennisnet is beginning to set up a numerical identification system to pseudonymise pupil data. Van Bruggen reports that:

> The system ensures that identification numbers of no further personal significance can be exchanged within the education supply chain without pupils' personal details being shared with and between providers of educational resources. The number is a pseudonym; in other words, institutions and

[27] https://github.com/HumanDynamics/openPDS
[28] https://www.kennisnet.nl/

> commercial suppliers cannot trace the number back to any personal information. Among other things, this system makes it possible to restrict the parties that track pupil progress to those authorised to do so (usually the school), with the pupils' privacy being well protected. (Van Bruggen 2015)

Design work has already been completed, but even with the pseudonymisation of data, the Ministry of Education will need 18 to 24 months to adopt the legal exemption that is needed for the system to be implemented. While the legal framework is being put in place, Kennisnet will be building and testing the system in cooperation with practitioners and suppliers.

4.10.3. Watchme

The WATCHME project[29], funded by the European Commission investigates how an e-portfolio enriched with student models can improve workplace-based learning by offering just-in-time feedback and adequate visualisation of relevant information. The architecture (Figure 20) has been designed to provide these services while maintaining the maximum possible degree of privacy.

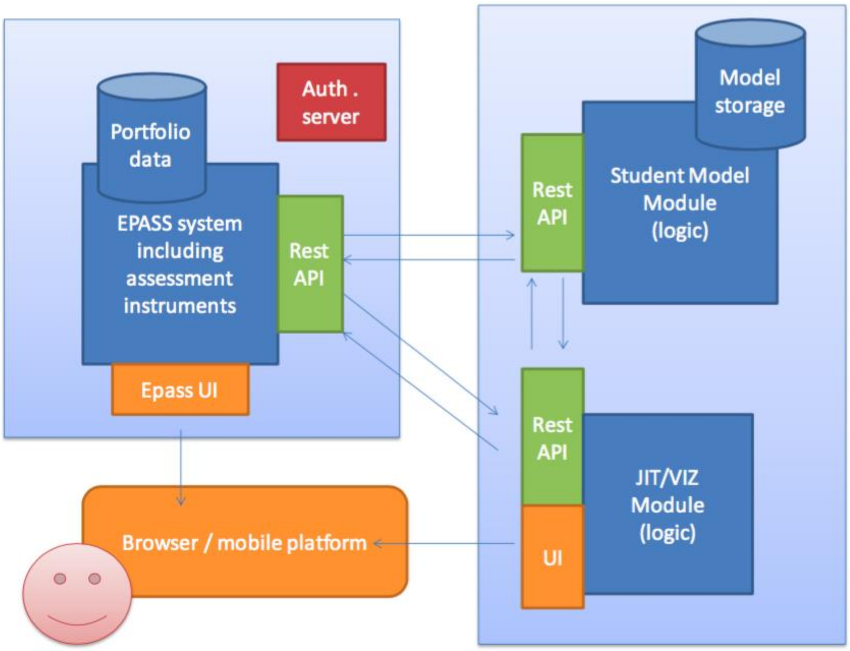

Figure 20: Conceptual overview of the WATCHME architecture. Source: Watchme Project (2014)

The EPASS portfolio system is the core system in this architecture, and the system has multiple security levels. However, the modules will reside on separate systems; therefore, the Student Model Module will store as little privacy-related information as possible. Privacy enhanced keys will be used to identify users; any information received by the Student Model module will be erased after being processed; and models and model parts that have become obsolete will be erased. The portfolios are owned by the users, and they determine who can access their portfolio and when.

5. Fit with requirements and user engagement

5.1. The problem of user requirements for learning analytics interoperability

It is clear that LA interoperability work that we have surveyed in sections 4 and 5 corresponds to a perceived need that is shared sufficiently widely in the education sector to provide impetus to the

[29] www.project-watchme.eu

initiatives that are taking the process forward. One might hope that the development of specifications and architectures would follow on from a widespread requirements gathering process in all educational sectors in a representative number of countries. In practice we have seen very little evidence of the collection or requirements, or of direct consultation with user groups in the development of specifications (see comments on the ISO process in Section 4.9). There may well be good reasons for this lack of consultation. The sheer complexity of the educational environment, and the difficulty of explaining the issues to stakeholders mean that the problems faced by a bottom up implementation of LA interoperability are daunting, and perhaps overwhelming. UK and Australian readers may be put in mind of the eFramework initiative (Olivier et al. 2005), which sought to create a service-oriented architecture for eLearning. The eFramework started work by creating shared domain models, but this process proved very challenging and the energy behind the initiative was dissipated. LA interoperability is a problem of similar dimensions, tighter in its technical focus, but wider in its domains of application. In addition to the complexity of the environment, we have noted above that the intention of LA is to transform the education system, rather than to serve those present requirements which can be documented.

Given these issues, it is understandable that the developers of specifications and architectures for LA interoperability have adopted a strategy of identifying technological ecosystems which are used in the sector, seeking to understand the drivers and constraints which impinge on institutions, and then making proposals for what needs to be done if open and standards-based learning analytics is to live up to its promise. This approach is directly expressed by Miller in describing his work in guiding the development of the xAPI interoperability specification:

> As thought leaders in a rapidly progressing community, we've tasked ourselves with trying to figure out what the next thing is that the community will want, or more importantly need… (Miller 2014b)

However, the design of technical specifications for LA has consequences for their target field of application which may not be foreseen or understood by the authors, or which may take up one side of a contested social issue while ignoring the other. If they are to avoid becoming a technocratic imposition with unforeseeable consequences, then stakeholders need to engage with the process in some way. Greller and Drachsler (2012) propose a possible framework for the dimensions of this discussion.

This section does not, therefore, set out the requirements of the education sector as an input to the interoperability process, as we see this as a gargantuan task, and one which is probably impossible to carry out. Rather we build on the activities of the LACE project to characterise the readiness of education sectors and national authorities to engage with the interoperability processes that we have described above. In addition to desk research, we draw on consultation with LACE community contacts, study of the LACE evidence hub, and our connections with standards communities. The structure of this section reflects the focus of the LACE project on schools, higher education, and the workplace, and the work-packages responsible for these areas have provided input to the relevant sections.

5.2. Interoperability requirements by sector

5.2.1. Schools

In the School sector the requirements that are expressed for analytics are strongly linked to demands from regulatory bodies for greater accountability from schools, and from parents wanting to follow the progress of the child, so that they can communicate more efficiently with the schools. Much of this agenda is driven from the centre by ministries of education, which deals with much of the decision making on programs and on infrastructure (especially that which is beyond the confines of an individual school). The policies of the current UK government and its predecessor are good examples of this trend, but it is to be found to differing degrees internationally. Schools do not have the capacity nor the incentive to develop their own ecosystem of applications to meet these needs, or the interoperability strategy which would need to accompany this, and so they either make use of state-provisioned software, or they turn to vendors. Nor, in many cases, do ministries of education have the appetite to undertake this task.

We have found very little published evidence of the collection or collation of stakeholder needs in the schools sector, nor did we find evidence of national interoperability initiatives. In order to confirm if this was an accurate picture of the European school sector we consulted with European ministries of education. We decided to extend the scope of our questions beyond interoperability per se, because knowledge of any initiatives driven by ministries of education would enable us to drill down to requirements. The survey was delivered in collaboration with European Schoolnet, a network of 31 ministries of education. The people targeted by the questionnaire were typically decision-shapers or senior civil servants working with issues related to ICT in schools. 25 national representatives were contacted, but only five responses were received, one of which contained no information. Information was obtained from Switzerland, Denmark, Norway and Turkey, and this was supplemented by information from LACE participants for the Netherlands and Sweden.

The results show that little is happening yet regarding learning analytics in the European school sector, directly or indirectly involving the formulation of needs or requirements, and that there is little readiness at national level to engage as stakeholders in the LA interoperability process. For example, in **Switzerland** the team at Educa.ch report that they

> ...do not know about any concrete learning analytics project in Switzerland. Learning analytics is just becoming an issue… For example, in Switzerland the EDK (representing the cantons) is carrying out the assessment on the basic skills of Swiss pupils with web-based tests, and they (including educa.ch) notice now that we will get data that we could use further in the horizon of learning analytics.

This opportunistic approach seems to be typical of many countries. Nevertheless, some answers reveal that countries are starting to discuss these issues, in particular Denmark and the Netherlands.

In their response **Denmark** describes a number of initiatives related to interoperability. Denmark is in an initial clarification phase where suppliers of learning platforms and producers of learning resources are making systems that can create data and handle data-supported education. 4-5 platform vendors are providing progression data against learning objectives. At the same time more and more digital learning resources from proprietary vendors include some learning analytics. Denmark has initiated around ten different projects in their national IT services in order to create an integration platform as part of the User Portal initiative[30]. These include a national repository of learning resources and access to a large virtual library, national online tests and national measurements of well-being in primary and lower secondary schools, a digital application process for enrolment to secondary and higher education and a data warehouse and business intelligence environment that gathers data on the entire education sector. The Danish representatives in our survey said that Denmark was working to move from management information to data for teaching and learning. For example, the national online tests are also for use by teachers in their daily teaching. The data are to be used for more than summative management information. Thus it appears that Denmark is building the foundation for learning analytics and improved interoperability of data, on the basis that this will provide opportunities for valuable services to be provided. But as far as we can tell the ministry does not have a position on what those services should be, nor is there a plan for how stakeholders will engage with that infrastructure to input their requirements.

The situation in the **Netherlands** seems to be similar to Denmark, with a particular focus on data privacy. In Section 4.10 above we outlined the initial work being carried out by Kennisnet to safeguard the privacy of students at the same time as making sure that parties in the education supply chain receive the data they need. This addresses the interoperability need of making data transfer compatible with the legal framework of the country and with educational policy, a challenge which is also felt in other countries.

Several other countries have been working on the solutions for single sign on, such as those established in **Norway** and **Sweden**[31], which could potentially be developed into services that are useful for LA. Another area where the Nordic countries are establishing a very basic infrastructure for coming learning analytic applications are to make curriculum documents digitally available for machine reading.

Some countries have reported occasional examples of projects that have some relation to interoperability and learning analytics. These include **Turkey** who is creating the conditions for relating student results to different targets in the curriculum. Teachers will soon have the possibility to digitally relate their own planning of their teaching to the curriculum targets.

Learning analytics and evidence-based educational management.

In the School sector the requirements which are expressed for learning analytics are strongly linked to demands from regulatory bodies for greater accountability from schools, and from parents wanting to follow the progress of the child, so that they can communicate more efficiently with the schools. Much of this agenda is driven from the centre by ministries of education, which deals with much of the decision-making on programs and on infrastructure (especially that which is beyond the confines of an individual school). Schools do not have the capacity, nor the incentive, to develop their own ecosystem of applications to meet these needs, or the interoperability strategy that would need to accompany this, and so they either make use of state-provisioned software, or they turn to vendors.

[30] http://www.stil.dk/Projekter-og-initiativer/Brugerportal
[31] https://www.skolfederation.se

In many cases there is also little appetite for the task of creating technical ecosystems on the part of ministries of education, but an exception has been the **United Kingdom**. In May 2013 the UK Department of Education under the Conservative and Liberal Democrat coalition government published an Analytical Review (Department for Education 2013a) on the role of research, analysis and data. This gives an idea of the key requirements which the then government saw for the use of data in schools, and there is little to suggest that these priorities have since changed. The review called for the promotion and use of robust quantitative evidence by both practitioners in the sector and policy makers, and linked this explicitly to evidence based policy (Goldacre 2013). The response of the government was “cutting guidance and providing more data and clear accountability so that there is an effective way to improve performance” (Department of Education 2013b, p.3). One measure was to “championing a move to more quantitative analysis with greater numbers of randomised controlled trials in schools” (Department of Education 2013b, p.4).

Learning analytics is not mentioned per se in this review, although there is a separate report on Data Systems written by Roger Plant, an independent Education Management Professional. The report sets the tone by stating: “Data is the fuel for the intellectually curious education and children’s services community and is essential to an evidence based system. Data is, however, sometimes felt to be a burden and not a driver for improvement.” (Plant 2013, p.3) To rectify this the report concludes with a number of recommendations, the main one being that the Department of Education should procure an interoperability system for exchange, use and maintenance of all data. An appropriate data model should be developed; data should be gathered and used in real-time, as part of the day-to-day business process; and data should be validated at source by a data validation service. In short, Mr. Plant proposed a Department for Education data warehouse as a one-stop-shop for all education and children’s services data in England, – a system that would be available through a web portal offering controlled access to reports and data extractions for the community.

Two news stories give a hint of what happened when plans were put into practice. In July 2012 ComputerworldUK reported that the “the Department for Education is planning a multi-million pound data aggregation project in a bid to create a platform that allows parents in the UK to easily compare and analyse different schools’ performance” (du Preez 2012). In September 2014 the paper reports “The Department for Education (DfE) has quietly dropped a £24 million project to create a platform for schools performance data” (Jee 2014). No explanations were offered; however, public minutes from the Information Standards Board from June 2015 show that that ministry has established a number of smaller pilots in “testing and learning as part of a pathfinder phase” to assess data models, and “to explore and learn about the movement of data from educational establishments and local authorities into the department” (Information Standards Board 2015, p.2). The central data warehouse model seems to have been abandoned. This failure is indicative of the difficulty of establishing policies for educational data management in the schools sector, even when the needs addressed are restricted to support for evidence based policy, and the initiative is well funded and politically supported.

5.2.2. Higher and Further Education

Universities and colleges, unlike schools, have substantial administrative autonomy and associated responsibilities, and so have a big incentive to decide on their own infrastructure and strategy. In many cases they also have technical capacity, and a research agenda that can be aligned with strategic priorities. These factors have led to the formation of a variety of active networks of institutions and regulatory bodies which seek to align policy and strategy and support academic and research network and services for higher and further education. Examples include GEANT[32] and PRACE[33], which are European networks, NORDUnet[34], which is a regional network, and the UNINETT[35] national education network for Norway. The degree to which LA is seen as being relevant varies between these bodies. There may seem to be a big leap from LA to high performance computing for research – the domain for the PRACE, but the work of GEANT on Authorisation and Authentication Infrastructure and Security is very relevant in an LA context.

These networks and organisations would seem to be fruitful sources for establishing LA needs, but our investigation indicates that learning analytics (let alone interoperability requirements for LA) has hardly surfaced on the agenda of these regional and European organisations. Where work related to digitisation in this field has been carried out, it has often involved adapting existing paper processes to electronic form. Some tentative steps have been taken. For example UNINETT, which operates the Norwegian research and education network and has contributed a specification[36] for logging and surveillance of digital examinations. The Norwegian project of which this specification is a part aims to make millions of exams digital within the next few years, and claims that a unified process would make it easier for the students to move between university courses. However, this and similar projects have been critiqued for having aims that are too restricted, only adding electricity to the unchanged paper based processes. Critics can point to the lack of deeper questions about the use of data, such as that posed by Cope and Kalantzis (2015): “Why, then, would we need summative assessments if we can analyze everything a student has done to learn, the evidence of learning they have left at every datapoint?” Such questions about the use of data in learning are at the heart of LA, in their absence usable needs to feed into the interoperability process will not be forthcoming. Thus these existing HE sectorial organisations are not in a position to provide an answer to the question ‘What are the LA needs of higher education stakeholders’. Into this void have stepped the various networks we have discussed above, which have the specific aim of connecting education with technology, which are mostly made up of HE institutions and representatives. To indicate the range of these organisations, they include

- SOLAR (an international research network)
- The Association for Learning Technology[37] (UK), Educause[38] (US) and The Spanish Network of Learning Analytics[39] (national research networks)
- Apereo (a foundation facilitating the development of educational software)
- The PAR Framework (an open not-for-profit provider of analytics-as-a-service)
- Jisc (a closed not-for-profit organisation dedicated to technology for HE)
- IMS Global Consortium Inc. (a closed educational technology interoperability specification group, including both HE institutions and vendors)

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32 http://www.geant.org/Pages/Home.aspx
33 http://www.prace-ri.eu
34 https://www.nordu.net
35 https://www.uninett.no/
36 https://www.ecampus.no/2015/10/20/ufs-149
37 https://altc.alt.ac.uk
38 http://www.educause.edu/
39 http://snola.deusto.es

- Unizen (a closed partnership of HE institutions developing shared learning technology capacity).
- The Data Interoperability Standards Consortium (an open data interoperability specification group including HE institutions, enterprise and governmental organizations, other specification groups and vendors)

This is not an exhaustive list, and it should also be remembered that there are many research projects in HE, which serve to link the user group with the developers of interoperability systems. These networks of HE institutions have driven the development of both LA in general, and LA interoperability in particular, not only in HE but across all sectors. This level of engagement is in contrast to the other sectors discussed here (schools and the workplace) where such activity is much more limited.

The challenge of identifying needs in a varied HE environment

As we have seen above, HE has strong connections with LA interoperability initiatives, with a potentially rich flow of requirements to interoperability systems developers. Unfortunately, however, HE institutions and practitioners are often not in a position to identify and share their own requirements. This has been shown by the experience of Jisc in the UK. In seeking to understand the needs that should inform the OLAA initiative, Jisc studied current practice in the sector in the UK. Sclater comments:

> As well as the sheer variety of motivations, a strong impression to emerge from the interviews is just what an early stage the UK is at in its understanding and deployment of learning analytics. Several participants wanted to clarify exactly what the interviewer meant by the term, and the activities discussed ranged from general business intelligence and the monitoring of key performance indicators, to tools which predict students at risk of failure, to systems which help manage the workflow around staff-student interactions. ... many institutions see the data as part of a continuum which can be used by people at every level of the organisation, from individual students and their tutors to educational researchers, to unit heads and to senior management. (Sclater 2014a, p.4)

This experience suggests that the huge variety of motivations, of levels of proficiency in analytics, and of user profiles make it exceedingly difficult to conduct a bottom up analysis of needs which can inform high level interoperability specifications and architectures. The design of individual applications, and the interventions made with them, can, and perhaps should, be designed in a participative way. Indeed Jisc is currently engaged in the collaborative design of a Student App for LA[40]. But this is a quite different matter from establishing the needs for specifications and architectures.

5.2.3. Industry / Workplace

In contrast to the high levels of participation of HE institutions in the development of LA interoperability systems, there has been little engagement on the part of industry, other than commercial providers of LA. There may be many reasons for this, but one factor is that while support for learning is a goal in itself for educational institutions, for commercial organisations learning is a means to the end of increasing the viability and profitability of the enterprise. LA can contribute to this goal by supporting automation, and informed decisions on processes. This perspective has substantial implications for the infrastructure that is required, with a need for links to production

[40] http://analytics.jiscinvolve.org/wp/2015/09/28/student-app-design-what-do-you-think/

processes. The LACE work package on workplace and training has carried out work to map out the distinctive learning analytics needs for industry. This led initially to the publication of the Learning Analytics at the Workplace Manifesto (Cardinali et al. 2015), which was followed up by another review paper 'Towards Learning Analytics Interoperability at the Workplace (LAW Profile)' (Cardinali 2015), which set out the criteria for an interoperability profile for LA at the workplace, and proposed candidate specifications. Both these papers are included in LACE deliverable 7.2, and readers are directed there[41] for more detail. Here we restrict ourselves to a summary of the main points.

Cardinali (2015), describes how the workplace is changing, with disruptive technologies dramatically altering the way people produce, distribute and purchase goods. In response to the shifting requirements of jobs the workforce needs to be continuously trained, both by educational institutions and by employers. The paper continues to examine how analytics and learning innovation could be blended to address this need by implementing working environments capable of constantly analysing, diagnosing and supporting the performance of users.

To give LA this role in business innovation will require a slightly different path from LA development for schools and university. Learning Analytics at the workplace will only make headway if and when learning technologies can interoperate with process management and analysis levels. This will demonstrate that new training initiatives and platforms are useful in helping organisations and their workforce gain maturity and proficiency with which to face the challenges of changing markets. Cardinali (2015, p.2) identifies the key challenges in achieving this as follows:

- The value of Learning Analytics will be in its capability to support workforces in moving away from descriptive and diagnostic observation and towards predictive and prescriptive analysis that is related to the underlying working processes and company goals.
- To be successful at the workplace, Learning Analytics will need to move rapidly away from measuring 'traditional' KPIs defined for human observation of formal education (e.g. course attendance, fall out rates, assessments) and towards the automated relation of training and performance support aids into their effectiveness to improve overall process activities and performances.

Consequently, new LA ecosystems for the workplace must be capable of aligning learning metrics with process aspects when dealing with industry maturity modelling scenarios. It will be a crucial success factor for LA in Industry that it should be able to 'observe and measure' the efficiency and effectiveness of new training solutions whilst matching them to the specific KPIs of the processes they aim to support in the workforce

The mapping between learning and skills levels, and industry KPIs and other manufacturing control and business functions is therefore an essential area for further development. For example, ISA-95, the Enterprise-Control System Integration standard[42] provides the semantics for mapping low-level metrics to high end KPIs understandable at organizational and financial levels, but lacks a focus on learning and skills levels. Cardinali (2015) lists the different standard bodies and their specifications that should be taken into consideration reaping the benefits of LA through achieving interoperability with existing industry processes. A visual representation of this landscape is given in Figure 21:

[41] http://www.laceproject.eu/deliverables/d7-2-data-sharing-roadmap/
[42] https://www.isa.org/isa95/

Interoperability scenarios for the workplace. Source: Cardinali (2015). A tabular representation with links to the identified specifications is available in the full paper.

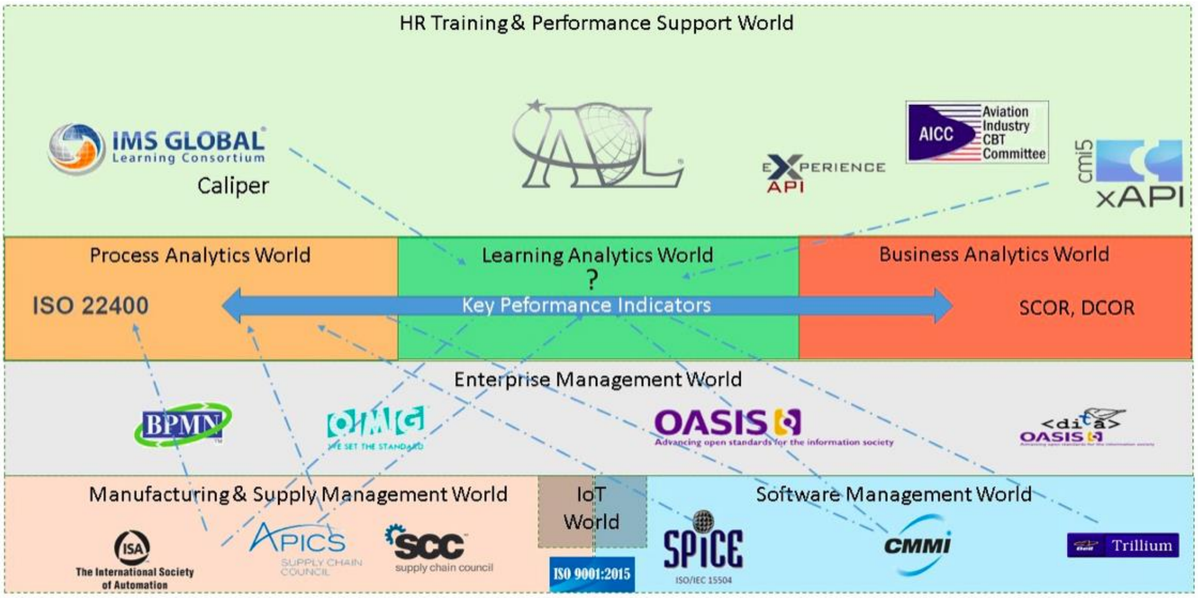

Figure 21: Interoperability scenarios for the workplace. Source: Cardinali (2015)

5.3. Requirements identified through ISO work on learning analytics

Education is a national responsibility, but educational policies have often regional and even local flavours, and responsibilities are often, to varying degrees, delegated. One might therefore expect that requirements for new learning technologies could thus be constructed bottom-up, from national and local requirements. But this is not always the case. International trends and market pressures introduce new products and methods, which often are retrofitted into local or national architectures and organisational and legal frameworks. There is no unified narrative to be found of local requirements being aggregated and brought to European or international standardisation fora for harmonisation. When looking at the responses to calls for use cases from ISO SC36, however, we can start to see a picture forming of some central issues national governments want to address.

Canada, United Kingdom, China, Japan, Norway, Korea, Germany, Australia, and France contributed to the requirements solicited by ISO/IEC JTC 1/SC36. In the June 2015 meeting of the subcommittee the Ad Hoc group reported[43] a number of use cases falling into four categories: Analytics Service, Assessment, Data Flow and Exchange, and Accessibility Preferences. The titles of the uses cases give an idea of what the national experts wanted to bring to the table:

- Analytics dashboards on LMS/VLE
- Predictive Analytics using trajectory data
- Personalized learning environments with digital resources
- Social network analytics
- Discourse analytics
- Changing assessment through the learning analytics (in high level concept)
- Developmental assessment based on the learning analytics

[43] ISO/IEC JTC 1/SC36 document N3086 (the document available to subcommittee members only)

- Learning activity data flow and exchange
- Kennisnet Student Data Control
- ePortfolio management using analytics
- Learning data utilization for research activities / privacy issues and research ethics
- Identity protection and identification
- Learning Analytics Supporting Accessibility Preferences
- Early detection and of accessibility needs to support adaptation to those needs
- Accessibility preferences stored in the cloud.

No definite conclusions can be drawn from these themes, because participation in standards bodies can be fleeting and the ideas proposed may not be the result of a rigorous process. It is however worth noting that five of the fifteen use cases addressed issues of data ownership and control, privacy, personalisation, and accessibility. This suggests, as might be expected, that these issues concerning the rights of the citizen are of greater concern to some national educational bodies than they may be to those researchers whose sphere of interest is restricted to the learning process per se. Looking more deeply into the national contributions we note the following:

Asian requirements: From the use cases presented and from available reports and academic paper contributions an observer of developments in this field in China, Korea and Japan is struck by how tightly LA is connected to assessment. Designers of online assessments are concerned about issues of reliability and validity of the tests and how to prevent cheating. LA is seen as useful for monitoring how students are managing learning and solving problems. In a LACE guest blog post (Cho 2015a) the Korean convenor of the ISO learning analytics working group and principal researcher at the Korean schools agency (KERIS) explains how competency and curriculum mapping drives the development of LA in his country. The system they have in mind seems to be a nationwide LMS with integrated learning portfolio services (Figure 22).

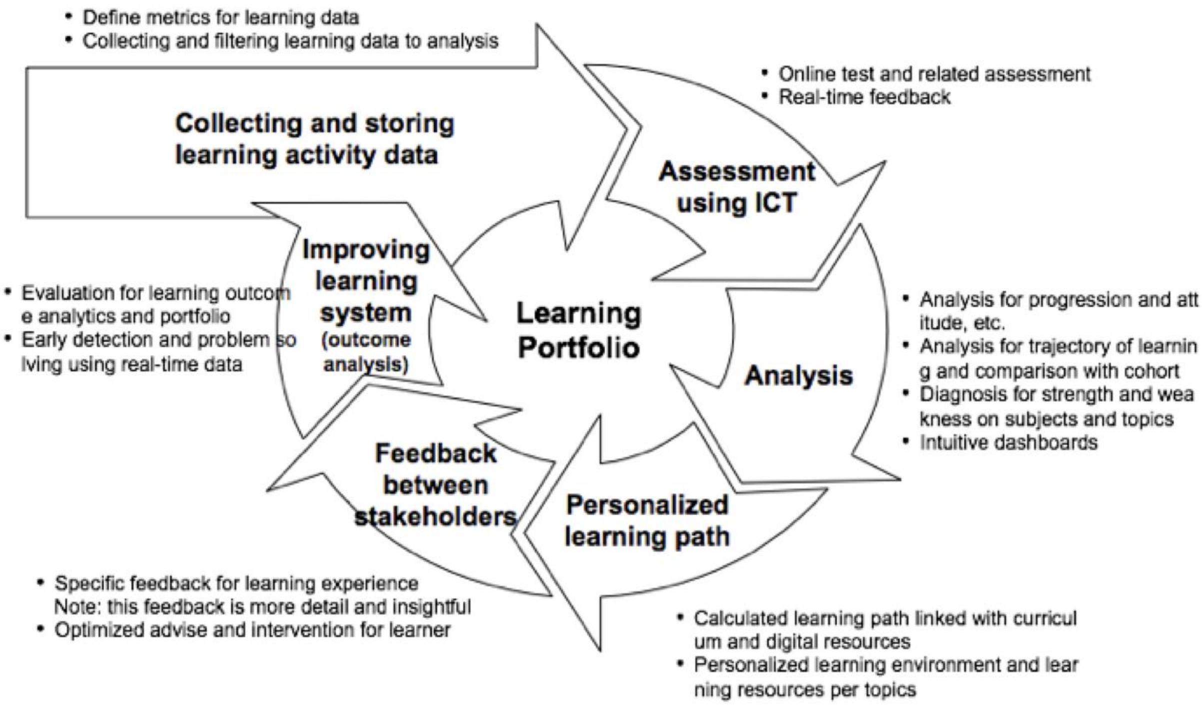

Figure 22: Ideas for a Learning Portfolio system based on learning analytics. Source: Yong-Sang Cho, KERIS, Republic of Korea

As part of the national development, KERIS is building an open source implementation of an LA system as a proof of concept (and an input to the ISO/IEC JTC 1/SC36 work).

European requirements: contributions to international standardisation show that European stakeholders are particularly concerned about issues of data protection and privacy (not to say that this is absent from an international agenda). Kennisnet, the Dutch school agency, is the actor that has put forward[44] the most concrete requirements for a "privacy solution" by presenting a mock-up based User Managed Access specification[45] of the Kantara initiative. The solution has still to be piloted. Also the higher education sector in the Netherlands have organised activities for LA, a special interest group is organised under SURF, the collaborative ICT organisation for Dutch higher education and research. Jisc, which is not a national body but which has national reach in the UK, has also placed stress on privacy and control of data, as we will see below.

In Norway a group under Standard Norway convened by a representative of The Norwegian Centre for ICT in Education in autumn 2015 started scoping new work items in learning analytics. Three projects have emerged, 1) a report on codes of ethics for learning analytics, 2) a report on access to and aggregation of data sources for learning analytics, and 3) vocabularies for describing activity streams implementing xAPI or IMS Caliper in a Norwegian context. These projects will be discussed with the stakeholders and commenced beginning of 2016.

Formal standardisation is just one line of conversation leading to a more harmonised view on the challenges and affordances of new learning technologies. A successful ISO standard could potentially be influential in global markets. However, there are very few examples of successful ISO standards in this field. What we are left with is the hope that a formal standards track, with negotiations going back and forth between national and international levels could progress issues of global concern that need international backing to be addressed locally. ISO SC36 is starting with publishing technical reports that are more designed to create consensus about broad processes than to produce code that could be implemented. At the current state of affairs, there is no doubt about the need to get a unified and well specified LA framework that allows different stakeholders to find their positions. If some of processes that have been ignored up till now, e.g., all issues related to ownership and governance of data, are addressed appropriately ISO standards could play a role within a broader standards ecosystem.

5.4. Concluding remarks on fit with requirements and engagement

In the introduction to this section we argued that bottom up user needs analysis is not a feasible approach for LA interoperability systems. Rather, the task is to identify technological ecosystems which are used in a sector, to understand the mission, drivers and constraints which impinge on institutions, and to make informed proposals for what needs to be done if open and standards-based learning analytics is to live up to its promise. This approach, while more practicable, is nevertheless fraught with difficulties. Firstly, the designers of specifications, architectures and systems need to adsorb a great deal of detail about the deployment context if they are to achieve adoption. The fate of the Analytical Review mentioned in 5.2.1 indicates the scale of this practical

[44] http://www.laceproject.eu/blog/international-interest-for-privacy-solution-in-education/
[45] http://kantarainitiative.org/confluence/display/uma/Home

challenge, as does the lack of adoption of IMS LD[46], a specification that was designed to support adaptive learning based on analysis of users activity. Secondly, and perhaps more importantly, the methods used to bring data together, and the constraints that these methods impose, can have unexpected but profound effects on the context in which they are implemented. This can lead to rejection of the system, or to undesired changes being imposed on the user group.

As we have seen above, however, the three sectors which we have discussed in section 5 vary widely in their capacity to engage with the design of LA interoperability systems. Moreover, within each sector there is a great variation in readiness. On the whole, the ability of the sectors to understand the issues involved and to engage in the interoperability process is less than one might expect. The necessary knowledge is available, but it is fragmented among a widely spread population. Both SOLAR and Apereo have demonstrated how a community of informed interested parties can engage in the interoperability process in HE, but this is only a start. A concerted effort with appropriate funding is needed to enable user groups to engage with design of specifications and architectures as widely as possible, so as to maximise the prospects for adoption, and to minimise the likelihood of unintended and undesirable consequences.

6. Piloting and adoption

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.

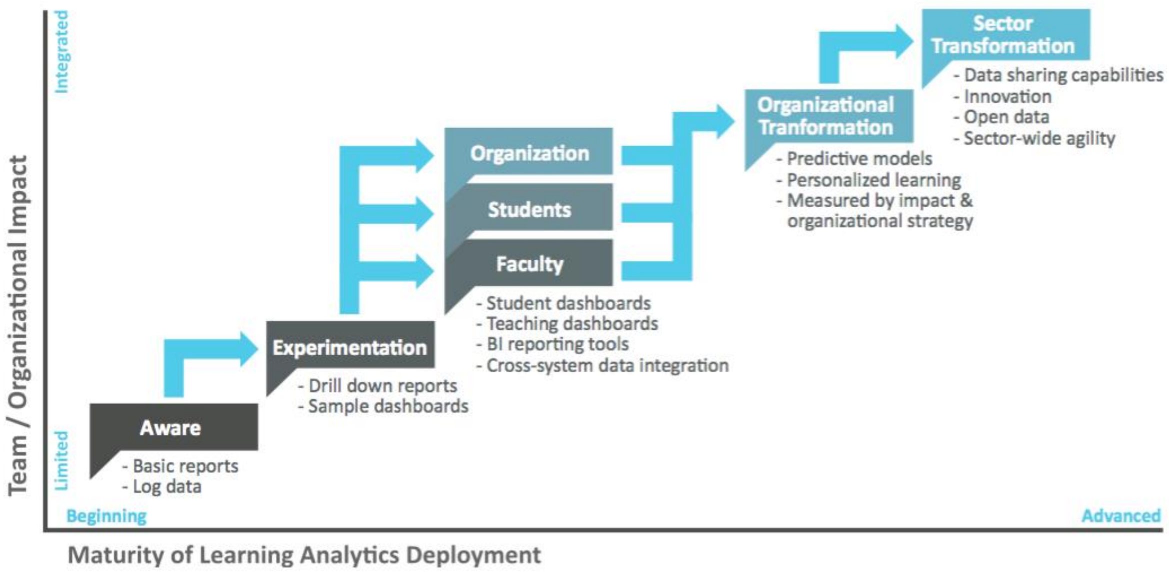

Figure 23: Learning Analytics Sophistication Model. Source: Siemens et al. (2013)

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

[46] http://www.imsglobal.org/learningdesign/

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.

6.1. Piloting and adoption of interoperability specifications and architectures driven by national agencies

LA has the potential to transform the way that education is conducted, and so one might expect adoption to be driven at the national level. The LACE project has searched for such initiatives in LA interoperability, but many countries have little activity at a national level. This is true for countries which are in the vanguard of LA, such as **Canada** and the **USA**, and also for large countries where one might expect there to be a need for national intervention. For example, LACE associate partner Maxim Skryabin reports that in **Russia** TEL innovation is focused on the National Open Education Platform that was launched in 2015. At present standardisation efforts for this platform are focused more on credit transfer mechanisms, although the assessment of learner trajectories has been identified as future work. In the USA Educause has taken on a leadership role, as has JISC in the UK, but such organisations do not have control over the national policies that can determine adoption.

In Europe some valuable work is being carried out in some sectors. Indeed the Jisc infrastructure discussed above could also be partially discussed as an adoption of xAPI and the PAR framework. Other countries are making an effort to move towards interoperability. For example, at a LACE workshop during the LAK'15 conference (Ferguson et al. 2015) Tammets reported on the development of an Educational Cloud funded by the **Estonian Ministry of Education and Science**. The aim in Estonia is to create a digital ecosystem and toolsets for managing and accessing digital resources that are produced and hosted by various content providers. As part of the initiative, learning analytics will be supported in secondary education. The Educational Cloud aggregates and makes accessible metadata related to digital learning resources such as e-textbooks that are located in different repositories. The system will track interactions with these collections and related resources and aggregated interaction data will be collected in a learning record store. All the components of these projects make use of the xAPI specification. The Estonian initiative is typical, however, in that it seeks to resolve the problems of a particular sector (in this case secondary schools), just as Jisc's work focuses on HE. This is a worthy goal, but it does not offer the cross-sector interoperability that one might hope for from a national policy. It seems likely that this reflects the separation of ministerial responsibilities for schools and higher education in many countries.

Two countries which have made a strong effort to support LA Interoperability initiatives are Australia and South Korea, although still within specific sectors. The **Office for Learning and Teaching (OLT) of the Australian Government** has fostered a strong analytics community in Australia, and have funded a number of strategic projects, some of which we discuss in the following section. According to Kitto "In some senses OLT is the equivalent of Jisc, but it is not trying to define the infrastructure. The implementation is at the institutional level" (Griffiths 2015b). The OLT has issued a number of reports in recent years which serve to bring coherence to the work being done in Australia. The first of these was a report commissioned from SOLAR on 'Improving the Quality and Productivity of the Higher Education Sector' (Siemens et al. 2013) and most recent being 'Student retention and learning analytics: A snapshot of Australian practices and a framework for advancement' (Colvin et al. 2015). In **South Korea** LA interoperability work is being driven by the Korea Education and Research Information Service (KERIS). In a LACE guest blog Yong-Sang Cho, principal researcher at

KERIS, described a three year research project funded by the Korean government, which has three main tasks.

- First task is to design workflow and to setup the test bed for reference model of learning analytics using open source software. …
- Second task is to develop standards for metric profile and data collecting API. This task is tightly combined with IMS Caliper project of IMS Global Learning Consortium. To improve accuracy for analytics my team believes that standardized data metrics is a mandatorily requirement rather than individual log data format.”
- The last task is to design a linked data framework for curriculum standards to connect with digital resources. This linked data profile is very useful when an analytics platform find weaknesses on the competency map for learners. It means that the analytics platform shows recommended personalized learning path with learning material derived from linked data search engine. (Cho 2015a)

At the 2015 Conference on Education Research in Seoul Dr. Cho and Professor Lee demonstrated a reference architecture referred to in the first task above (Cho 2015b). The architecture is envisioned to provide proof of concept for the more abstract work being done in SC36/WP8, and seems to be heavily influenced by IMS Caliper and other IMS specifications, in particular Learning Tools Interoperability. They demonstrated a solution that lets the user open an e-textbook from a list of resources held in a LMS, read through the book in a Readium application, and have the progress captured and reported to a separate visualisation tool through the use of an activity stream specification generating RDF formatted data. The plan is to further develop this reference architecture to cover all parts of a learning analytics system.

In **Japan** coordination in LA is being led by the Japanese Society for Learning Analytics (JASLA)[47] established in May 2015 with Professor Yasuhisa Tamura as chair. JASLA aims to study, do research and disseminate ideas and results on learning analytics in Japan. According to professor Tamura only some universities in Japan have started experimental projects on LA and Kyushu University has a leading role. Among other projects, professor Hiroaki Ogata and his team are researching e-book use through analysing the log files (software support: BookLooper[48]). By 2020, the Ministry of Education, Culture, Sports, Science and Technology (MEXT) of Japan has planned to replace all textbooks for elementary, middle, and high schools with e-books. This initiative will boost interest in “Educational Big Data”, according to Professor Ogata. Kyushu University has also projects on automatic summarisation of lecture slides for student preview, error log analytics to improve course design, etc.

JASLA have not yet seen any projects in the public K-12 sector, however, some private schools have activities in this space. Textbook publishers, material publishers and external educational service vendors on the other side, are very eager to introduce LA in their business (this includes Gakken, Benesse and Recruit). Interoperability issues related to learning analytics are addressed by an industry consortium currently organising 119 corporations and organizations and 1,072 individuals,

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[47] http://jasla.jp
[48] BookLooper is a document viewer system for personal computers and smartphones provided by Kyocera Communication Systems Co., Ltd.

ICT Connect 21[49]. This consortium aims at coordinating technical specifications around digitization of education, and to promote utilization of digital-based classroom activities. Members are major textbook publishers, material vendors, educational service providers (incl. EdTech), national and regional officials.

In the cases discussed in this section, there is little significant work being done at a national level on the development of interoperability specifications and architectures (with the exception of Jisc). Rather, national efforts tend to support the profiling, localisation and piloting of existing international initiatives, and feeding their results back into the wider context. Indeed it may well be that this is the most appropriate role for national agencies, and will help to avoid the dangers of fragmentation.

6.2. Piloting and adoption of xAPI

There are 164 organisations mentioned xAPI adopters on the TinCan API website[50]. 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 Apereo and Jisc architectures, as this creates an environment where large scale use of the specification by education institutions becomes a practicable option. We have discussed the details of this work in section 4.3 and 4.4, and do not repeat them here. The success or otherwise of these initiatives will have a great impact on adoption, but it is too early to forecast their success, as we discuss below.

A number of companies are working on xAPI implementations, many of which participate in the community around Connections Forum[51] and xAPI Quarterly[52], and there is also an xAPI group in Australia coordinated around the TinCan at Work[53] community website. The Connections Forum is a particularly valuable source of information on xAPI adoption, and some examples of adoption from this source include the following.

Float. Float have built **Tappestry** “the first mobile app to enable employees to record what they learn, aims to capture valuable knowledge and intellectual property that might otherwise be lost to the organization” (Float Mobile Learning n.d.), which was available at the public launch of the beta for xAPI 0.90. Everything that happens in the Tappestry social network is related to an xAPI event (Udell 2015). More information on Tappestry is available in a white paper published by Float (Woodill 2012). Float have also made available an iOS xAPI software development kit[54].

RISC. RISC has “created a series of data visualizations to provide dashboard and drill-down reporting into xAPI data. In response to a client request for better analytics to track learner interactions with

[49] https://ictconnect21.jp
[50] http://tincanapi.com/adopters/
[51] http://connectionsforum.com/
[52] http://xapiquarterly.com
[53] http://ideasatwork.com.au/blog/category/ideasatwork/tincanatwork/
[54] See http://gowithfloat.com/2012/12/getting-started-with-the-tin-can-ios-sdk-part-1-of-2/ and http://info.floatlearning.com/free-xapikit-demo

content, RISC collaborated with MakingBetter to design a first-of-its-kind tool empowering learning professionals to see how their content is being used, identify where students have questions, and streamline training materials" (Learning Solutions 2015b). A video presentation about this work is also available[55].

Link with IEEE Actional Data Book (ADB). John Costa, chair of IEEE ADB, has proposed a 'first scenario case study to demonstrate how xAPI learning records data are leveraged to give feedback (visualization) to learners in real time right inside the learning content — an ebook in this story'. (Classroom Aid 2015)

Cognitive Advisors. The TREK Learning Experience Manager is 'built from the ground up' using xAPI. It is "a mobile cloud-based application that manages, captures, and tracks experiential learning (real world, on-the-job experiences) and informal learning (like coaching conversations, looking things up, or viewing brief videos). It enables the creation of learning paths that optimize the path to achievement of key competencies, awards badges to recognize achievements, and provides learning analytics to tie learning to business results." (Learning Solutions 2015a)

Riptide. Riptide have two products making use of xAPI. Riptide Reaper[56] collects data from live firing ranges using the xAPI and stores this in a Learning Record Store (LRS) for analysis. Riptide also uses xAPI in a system for Wizz Airlines, which gathers data from in-flight sales and deploys this to award training points to flight staff. Both these applications are described in a video presentation from the xAPI Boot Camp 2015 (Washburn 2015).

Yet. Yet Core provides 'a platform for collecting and visualizing learning, training, and human performance data derived from any source' (Blake-Plock 2015b). Shelly Blake-Plock describes this work in an xAPI Boot Camp presentation, explaining how it uses xAPI for on-boarding junior developers in a company that has a GitHub repository, and needs to know that junior developers are competent at using it. *Yet* built a bridge to pull data from the activity streams in GitHub and capture them in an LRS, providing access to the entire social graph of GitHub in real time. (Blake-Plock 2015a)

OnPoint. The OnPoint Learning and Performance Suite highlights a number of applications of xAPI (Gadd 2015).

- Attendance tracking for webinars and events
- Getting xAPI out of SCORM or Flash by building a wrapper that can create an xAPI statement
- Enabling an Android device which is disconnected from services to create statements that are uploaded when reconnected.

The Connected Learning Analytics Toolkit has been an important project in moving forward the xAPI specification. This is part of the project 'Enabling connected learning via open source analytics in the wild: learning analytics beyond the LMS'[57], and it is sponsored by the Australian Government's Office for Learning and Teaching. The project is led by Kitto, who has explained in a LACE interview

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[55] See http://connectionsforum.com/vimeo-video/art-werkenthin/
[56] http://adlnet.gov/reaper/
[57] http://www.olt.gov.au/project-enabling-connected-learning-open-source-analytics-wild-learning-analytics-beyond-lms-2014

(Griffiths 2015b) 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 2015b). 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.

The relevance of CLA in the context of this report is that the team are exploring in practical terms what is possible with xAPI, by developing a connected learning recipe (i.e. profile). In a video presentation transcribed by the present authors Kitto and Bakharia conclude that:

> xAPI is a good way to represent what we need to represent, recording what is happening in social media. But particularly we run a number of stumbling blocks with the learning report stores. … As soon as you want to do any interesting analytics using xAPI you run into barriers. … We still run into problems with recipes and definitions of vocabularies. The standard is actually in a danger of proliferation of the same thing that is happening in everyone's separate little systems, and at that point analytics goes out of the window. … There's a step in the right direction with recipes and the recipe registry, but what we are not seeing is a lot of adoption. ...there are two layers to the problem. So we may have a controlled vocabulary of verbs, but then we'll get proliferation at the next level. So how do we actually make sure that there is only one recipe for a particular usage, and how can you actually then take that actual recipe standard and use it in your reporting and your evidence? (Kitto & Bakharia 2015)

In a comment on a draft of this report Silvers discussed the problem identified by Kitto and Bakharia.

> A federated registry for profiles, verbs, etc. with a service architecture allowing developers to incorporate these official sets dynamically will help. A move to a linked-data approach (like JSON-LD) will further help decomplect this issue. The registry is a priority for DISC. We expect there to be a special interest group activity around studying the impacts of switching to JSON-LD on existing implementations of both LRSs and Activity providers to make recommendations by the end of year 2016. (A. Silvers, January 5 2016, personal communication)

Kitto expands on the role of recipes in a LACE interview:

> Interoperability becomes easier when you are trying to do big things. When you talk about an event in an LMS it is almost impossible, but cognitive presence in a community of inquiry is easy. Recipes have to link into something interesting from the top down. Are you trying to find out about meta-cognition, or social capital? You will need to store different kinds of data. The connected recipe work we are doing is related to this. Designing the recipes from the top down is very important. Everyone is leaving

> it to the data interoperability wonks, which will lead to a stupid system. I want to see people pay more attention to their models. (Griffiths 2015b)

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. 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))

6.3. Piloting and adoption of IMS Caliper

Of the three documents which 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 who have the resources to proceed through a certification process, and who, 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 only two months before this report was completed there has been little time to assess the adoption of the specification. For example, Yong-Sang Cho (Cho 2015a) 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 such issues are simply teething problems 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.

6.4. Apereo Foundation and Jisc architectures

The Apereo Foundation is not, strictly speaking, the promoter of the 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 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.

7. Criteria for taking a decision on interoperability systems

At the time of writing this report (December 2015) much remains unclear about the strategies to be adopted by the creators of xAPI and IMS Caliper. As regards xAPI, there are plans for a Data

Interoperability Standards Consortium, a new, not-for-profit organization in the State of Pennsylvania, USA, which will be the steward of the specification (Silvers 2015b), and which will presumably take a lead in coordinating work around the specification. IMS Caliper was published in October 2015, and providers beyond the mainly US-based members of IMS have not yet had time to test and evaluate the specification. The practical results of the Apereo and Jisc initiatives are yet to be piloted at scale. Policy makers and educational managers therefore lack much of the information that they would like to have at their fingertips before taking decisions on the adoption of LA interoperability systems. Nevertheless, inaction also carries its risks in a fast moving context. In this section we suggest some ways in which to think about the different approaches to LA interoperability, and some criteria for distinguishing between the ecosystems which are starting to emerge around Caliper and xAPI.

7.1. LA and institutional strategy

LA touches, or has the potential to touch, all aspects of an educational institution's activities. Stakeholders from all parts of the institution are likely to have an opinion about the use and implementation of LA, and, similarly, the wider infrastructure for LA is composed of, or comes into contact with, most of the infrastructure of the institution. The result can be a tangled discourse, with many conversations at cross purposes, and difficulty in establishing institutional strategy.

In constraining this discussion we point to the key differentiating factor for LA: that it seeks to work with a wide range of learner activities, rather than with the largely static representations of content and results which have typified earlier approaches. This focus on activities is not a new idea, the thrust of the Learning Design movement, both in general terms and as regards IMS LD, had this aim. But the rise of LA is the first time that there has been momentum for a computational approach to understanding and enhancing learning activities.

Given this focus on learning activities, the key questions for institutions and their managers in seeking to understand LA are simple to formulate, but not easy to answer. They include:

- What are the key learning activities we are conducting?
- How do we understand those learning activities and their outputs?
- What data should we need to collect to support our understanding of learning activities?
- How will we generate our understanding of learning activities?

The answers given to these questions, and the way in which people go about answering them will have an influence on one's view of LA interoperability.

It is hard to obtain definitive answers to these questions, in part, because the responses will depend on the vantage point of the person who is answering. A teacher and a financial officer will have different views. The LACE project, which stands for "Learning Analytics Community Exchange", takes the position that these answers should come from a wide range of stakeholders. This implies that (a) there is an LA community which has something important to say, and (b) that some structure is required to support the engagement of the LA community with the technological and pedagogic developments that are driving the development of LA. These propositions also imply a certain stance towards the LA interoperability process, and commitment to the following methods:

- Open development processes. The decisions made in designing specifications and architectures for interoperability affect us all. Input from stakeholders helps to ensure that valuable functionality is not overlooked, and also to avoid inappropriate constraints and potentially negative consequences of technical specifications and architectures. This input can only be obtained by ensuring that specification development is open to a wide range of contributors, who are both technically capable and strongly connected to stakeholder groups. Consequently we believe that, wherever practicable, specifications and architectures should be developed using an open process. The Society for Learning Analytics Research (SOLAR), many of whose members work in HE, has provided a channel for some of this activity, since 2011 when it published *Open Learning Analytics: an integrated & modularized platform. Proposal to design, implement and evaluate an open platform to integrate heterogeneous learning analytics techniques.* (Siemens et al. 2011). The Apereo foundation has also taken a leading role in managing the development of open infrastructure for LA.
- Stakeholder engagement. The design of LA specifications involves many different stakeholders, including learners, teachers, IT staff, student support staff, careers services, librarians, parents, managers, and ministries of education. Each of these groups has their own perspective on the nature of LA and the requirements of LA systems. The standardisation process has an ethical duty to understand the effect of the systems that they are designing on the people who will be using them. Moreover, a failure to understand this impact on stakeholders can lead to ineffective systems and/or resentful users.
- Open Reference Architectures. Open source implementations of open reference architectures help the field to move forward, by providing shared artefacts for collaboration, and by facilitating piloting, testing and new input to R&D.

The LA landscape, however, includes many organisations and systems that do not make use of these methods. Many commercial organisations prefer to work with their own proprietary systems. These systems may be simpler to develop and manage, because all decision-making is in-house, and they may also confer competitive advantage and, potentially, control of the market. Organisations for whom these factors are a priority will tend to collaborate as and when they feel it is essential, and do so through closed consortia such as IMS and Unizin. Many of the most successful providers of LA systems offer closed proprietary products, and do not participate in open standardisation processes. In deciding on LA interoperability policy, managers and policy makers are therefore confronted by a contrast between specifications and architectures developed using open and closed methodologies. Managers and policy makers within education institutions have to establish a strategy in relation to this dichotomy. The view that they take will be related to their positions on a number of underlying issues. To suggest the range of possible views, the following table provides a set of indicative polarised positions.

Positions sympathetic to closed methodologies	**Positions sympathetic to open methodologies**
Vendors are experts, and can be relied upon to specify the best systems for my organisation. Our organisation is best served by buying-in best of breed applications.	A good fit with organisational needs can only be achieved by the involvement of a wide range of stakeholders in the development of specifications, and the local adaptation of highly flexible systems.
The problems of implementing LA are largely technical, and experts in sociology and pedagogy	Many of the problems of implementing LA flow from the wide range of professional, social and

should be left alone to find interoperability solutions.	cultural views of LA, and these should inform interoperability solutions.
Learning is fundamentally the same all over the world, and what works in Kentucky will also work in Alsace Lorraine and Burundi	Learning is culturally dependent, and interoperability systems should be designed to enable multiple approaches
Learning analytics systems can arbitrate on the effectiveness learning processes, and can guide the management of education. This is most effectively done using systems developed by external experts.	Learning analytics is a valuable support for educators, but local actors should arbitrate of effectiveness and success. This process is most effectively guided using systems which have mechanisms for meeting the needs of a wide range of stakeholders.
The problems of data privacy can be resolved by rigorous arrangements with third parties.	To enable appropriate data privacy policies, institutions must be able to choose which parts of their LA infrastructure they install locally, and which parts are managed remotely. Responsibility for data privacy is located in the individual, in the state, and at many levels in between.

Table 1: indicative positions towards interoperability approaches

It is not our purpose here to argue for or against any of these propositions, for two reasons. Firstly, the positions taken by an institution are dependent on local circumstances, of which we can know nothing. Both closed proprietary solutions and open systems are very popular, and we assume that the decision making which leads to these choices is coherent. Secondly, LA systems are composed of many parts, and institutions may well choose to mix open and closed systems for different purposes.

Nor are the differences between open and closed interoperability systems as clear as we have suggested. In the case of the open Jisc architecture, Webb (Griffiths, 2015c) has told LACE that for practical reasons the APIs for the system are being developed in closed discussions between the technical partners who are developing the applications (although they will be published when ready), and that some of the code being developed is "just Jisc cloud service, and so specific we wouldn't open source them". Similarly, the closed development of IMS Caliper has resulted in an open source reference implementation. There is therefore no simple contrast between closed design by experts, and open design with stakeholders, but rather a difference of emphasis and in consultation method and publication licenses.

Despite these provisos, however, we argue that policy makers and educational managers should recognise that decisions on LA interoperability systems are deeply entwined with sensitive educational issues, such as those we identify in Table 1: indicative positions towards interoperability approaches

7.2. Making sense of the emerging ecosystems around xAPI and Caliper

Thus there are many different approaches to LA, and many systems on offer, and a range of positions which can be taken towards open and closed systems. Overarching this complexity, however, is the need for institutions to adopt a stance with regard to the ecosystems which are growing up around IMS Caliper and xAPI. This may be to commit to one or the other, or to make use of both. We now discuss four of the differences between the specifications which may have strategic implications 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 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: 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 2015b).

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 three: openness to the wider ecosystem*.* 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. But the question is, how can you unify your description of xAPI and LMS events? … It is the responsibility of the LA community to demand that the two standards get serious about working together. But one of those standards is doing their best, and the other is not playing. … if the entire community moves fast and demands interoperability, and pushes things in the right way, you could end up with a proper data ownership. But it's a window, and if it closes it will be 15 years before we get another chance. (Griffiths 2015b)

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 even been put on the agenda of formal standardisation (ISO/IEC JTC 1/SC36 WG8). However, 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 2015a)

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). In our view, however, the refusal to collaborate with other ecosystems which make up the LA and eLearning landscape suggests strategic use of the closed status of the specification in order to achieve dominance of IMS Caliper and of the certified applications which make use of it. If this were to come about, we believe that it would impose unacceptable constraints on the future development of LA. We note that the episode described by Silvers, above, took place only a month before publication of the specification. It may be that IMS Global was not interested in the distractions of collaborating with xAPI at this critical point, and that in future greater flexibility will be shown. An alternative route to collaboration would be for IMS Global, or some of its members, to join the Data Interoperability Standards Consortium which is taking stewardship of xAPI.

It is too soon to come to a conclusion on this point, but we recommend that policy makers and managers should be aware of this issue, and should act accordingly as the positions of the various parties become clearer. We see the value of IMS Caliper, but we do not believe that it would be healthy for the LA infrastructure of the world to be decided by a closed group dominated by vendors.

Difference four: data protection. As we discussed in section 6 above, the issue of 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 which 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 a LACE guest blog post Kitto put forward that 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).

7.3. Technical constraints and user consultation

When we consider diagrams of architectures for interoperability and related technical documents they may appear to be impressive and consolidated plans, but in many cases they can more appropriately be considered discourse artefacts. When we contrast these representations, as we do in this report, we are making an intervention in the discourse, and making it from a particular standpoint. Our own position, following on from the discussion above, is that we are not confronted by a technical problem that requires a purely technical solution, but rather by a design process involving diverse groups. In our view, this is best carried out in an open design process using cooperative design principles.

Among the relevant constraints on the design process are the technological facts on the ground. It might be argued that a system where the Virtual Learning Environment / Learning Management System is not at the centre would provide a more effective and flexible environment. But an architecture that required abandonment of the VLE would face insuperable problems in adoption. Nevertheless, the dominance of technical arguments can lead to problems. The design of technical systems generates constraints and affordances for the institutions which use them, with consequences for the operation of those institutions and for the practice of the people who use them. This is particularly true for learning analytics, which is potentially a pervasive presence in education. Often constraints emerge because desired functionality simply cannot be achieved by using a given specification, and SCORM was often critiqued on this basis. But problems can also arise from the use of very open technical specifications. This is the case for xAPI, a successor to SCORM in some respects, which provides a technical solution for describing learner activity. It "has a structured but incredibly open way of dealing with data. This is its greatest strength and weakness. You can do anything you need to do with it, and you can make a big mess of the data in the process." (Bowe 2013). It might be argued, then, that xAPI sidesteps the problem of defining user needs for LA interoperability by providing very generic functionality. This may be a wise strategy, but it hands on the problem to a later stage when architectures and specifications become instantiated in real systems. Kitto reflects on how the generic functionality of the xAPI specification will have implications for educational practice:

> I think that xAPI is at a critical juncture, and it is important for the community to reflect upon its purpose at this point. What are we going to do with our xAPI data? Is it just for the managers and HR departments, or are we going to give it to the learner? What kinds of things do we want to report on? I would like to see xAPI data used to enable things like discourse analytics, creativity, metacognition, and life long personalised learning, but in order to do this we need to consider analytics and controlled vocabularies. I am looking forwards to a conversation about data extraction, complex analytics, and learner focused reporting…how can we use the standard to encourage higher order thinking in our learners? (Kitto & Bakharia 2015)

Similarly the Open Academic Analytics Initiative has identified a set of needs relating to the exchange of predictive models.

> Many questions exist in the emerging field of Learning Analytics with regards to the degree to which predictive models which are built based on data from one particular institution type and student population can be effectively deployed in academic contexts where the institution type and/or

> student population differ significantly. The degree to which predictive models may be "portable" has major implications for the scaling of learning analytics across multiple institutions and even higher education itself. (Lauría et al. 2013)

As Lauría and Kitto show, HE has many people who are capable of understanding and representing the needs of the sector from many perspectives. It is, we believe, essential that the bodies responsible for developing specifications and architectures for LA interoperability engage with informed representatives of stakeholders so that the emerging LA infrastructure does not result in systems which, for lack of communication, ignore or work against the needs of institutions, learners and teachers. The Apereo Foundation's Learning Analytics Initiative is perhaps the best example of this consultation process, and indeed the work of the Open Academic Analytics Initiative is continuing within this context.

Kitto's comments regarding the implications of xAPI for educational practice cited above (Kitto & Bakharia 2015) are an example of how stakeholders can contribute to this process. Such input to the standards process is essential, both to ensure that opportunities to provide valuable functionality are not overlooked, and also to avoid inappropriate constraints and potentially negative consequences of technical specifications and architectures. This input can only be obtained by ensuring that specification development is open to a wide range of contributors, who are both technically capable and strongly connected to stakeholder groups.

From the point of view of the institution, however, the improvement of technical specifications may seem a very distant goal when compared with the immediate practical problems of implementing an interoperability system. The individual institution does, however, have an immediate need to understand the full range of implications of their technological decisions. This need can be met by engagement in foundations and communities that host discussions of interoperability systems. Discussions of how to achieve technical goals is not sufficient in this respect. It is also important to examine the interaction between interoperability systems, organisations and users, and to share approaches to making appropriate technological choices in the light of this examination.

On this basis we recommend that policy makers and education managers engage in open innovation processes for interoperability systems, coupled with open source development of reference implementations, in order to serve their own institutional objectives, and to support the development of more effective systems. This engagement does not mean that institutions should not make use of closed proprietary systems, as we have made clear above. Rather we argue that engagement in open processes is an important step towards taking informed decisions. There are many contexts within which institutions can engage, including Apereo, SOLAR, PAR, as well as national contexts such as Jisc in the UK, and we expect these opportunities to expand to meet the variety of institutional dispositions for engagement.

7.4. The role of the European Commission and other funding bodies

The issues which we have described above in the context of educational institutions are also relevant to the policies of national agencies and of the European Union. In the discussion above we have focused on the choices to be made by managers and policy makers within institutions. For a single institution it may not be unreasonable to make a decision to work exclusively with a Caliper-based ecosystem, or an xAPI-based ecosystem. For the European Union, or for its member states, however, wider issues become important, regarding the development of the market as a whole and its influence on education systems. We believe that there is a need for plurality in the market, and that national and EU policy should be directed at supporting this plurality. This means that

1. Projects should be funded to pilot applications and methods which draw on both ecosystems
2. Systems should be put in place to share information about emerging LA interoperability solutions, and to clarify their significance to stakeholders
3. Support should be given for stakeholder engagement with both ecosystems. This is particularly relevant for the xAPI ecosystem, which both welcomes and requires community engagement. Such work would include network and community building, and international special interest groups.
4. Promotion of success stories
5. Support the formation of necessary organisational structures. For example Berg argues that xAPI profile consistency through a common set of transformations could lead to cost savings for institutions, but “to maintain a consistent usage of xAPI an authority would need to own and curate the transformations”.
6. Support for research and development of data protection solutions which meet the requirements of both the European Union and member states.

In order to ensure plurality and solutions that can be adapted to national requirements a strong case can be made for providing support for the key stakeholders to work through the Apereo Foundation to create a reference implementation, leading to large scale piloting and deployment.

There is also a need for leadership in the standardisation process. The CEN instruments for consensus building and harmonisation in this area are inactive, and so there is currently no pan-European instrument for harmonisation within the field of LA. It was suggested in the LACE project description of work that LACE could support consensus building, but the lack of CEN support and the immaturity of the market made this impossible. Now, with new specifications on the market, and a clear and present need for harmonisation, this need should be addressed with appropriate funding.

At the national level, policy makers should look carefully at the trail blazed by Jisc in developing an open learning analytics architecture that is adjusted to national requirements. There will be many lessons to be learned from this experience, and much of the work can surely be adapted to the needs of other countries. The fact that the Jisc OLAA is closely aligned with the Apereo Foundation makes this task of adaptation much easier. The creation of localised architectures or profiles can also be undertaken usefully by school agencies, or consortia of universities.

This is an exciting time to be writing a report on interoperability for LA, because the activity of recent years is coming to fruition in the publication of IMS Caliper, the consolidation of xAPI, and the development of a set of promising applications around the Apereo Foundation and Jisc architectures. We believe that there is every chance that all these systems have a viable future ahead of them. We have provided an overview of the most significant current developments, and analysed the choices and actions that are available to educational policy makers and managers. We hope that the information which we have presented, and the positions which we have outlined, will provide a stimulus to policy makers and managers at all levels to take an active role in developing interoperability. We have an opportunity to take the currently emerging specifications, architecture, systems and methods to achieve real learning analytics interoperability, but as Kitto has said "it's a window, and if it closes it will be 15 years before we get another chance" (Griffiths 2015b).

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10.About

10.1.1. Version History

Date	Notes	Person
2015-12-07	Version for internal review	Dai Griffiths
2016-01-02	Revised version for second internal review	Dai Griffiths

10.1.2. About this document

For more information, see the LACE Publication Policy *http://www.laceproject.eu/publication-policy/.*

10.1.3. About LACE

The LACE project brings together existing key European players in the fields of learning analytics & educational data mining who are committed to building communities of practice and sharing 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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