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Information technology for learning, education and training — Learning analytics interoperability —

Part 3:
Guidelines for data interoperability

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ISO copyright office
CP 401 • Ch. de Blandonnet 8
CH-1214 Vernier, Geneva
Phone: +41 22 749 01 11
Fax: +41 22 749 09 47
Email: copyright@iso.org
Website: www.iso.org

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Foreword

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Introduction

The increasing amount of data being generated from learning environments provides new opportunities to support learning, education and training (LET) in a number of new ways through learning analytics. Learning analytics is terminology that is used to refer to both an emerging field of discourse and an emerging technology. It spans the use of diverse sub-technologies, workflows and practices and is applied to a wide range of different purposes. For instance, learning analytics are being used to collect, explore and analyse diverse types and interrelationships of data, such as: learner interaction data related to usage of digital resources; teaching and learning activity logs; learning outcomes and structured data about programmes; curriculum and associated competencies.

As an emerging technology, learning analytics address a diverse group of stakeholders and cover a wide range of applications. Learning analytics raise new interoperability challenges related to data sharing; privacy, trust and control of data; quality of service, etc. The following issues are identified as general requirements for learning analytics applications.

For the learner:

— tracking learning activities and progression;

— tracking emotion, motivation and learning-readiness;

— early detection of learner's personal needs and preferences;

— improved feedback from analysing activities and assessments;

— early detection of learner non-performance (mobilizing remediation);

— personalized learning path and/or resources (recommendation).

For the teacher:

— tracking learners/group activities and progression;

— adaptive teacher response to observed learners' needs and behaviour;

— early detection of learner disengagement (mobilizing relevant support actions);

— increasing the range of activities that can be used for assessing performance;

— visualization of learning outcomes and activities for individuals and groups;

— providing evidence to help teacher improve the design of the learning experience and resources.

For the institution:

— tracking class/group activities and results;

— quality assurance monitoring;

— providing evidence to support the design of the learning environment;

— providing evidence to support improved retention strategies;

— support for course planning.

In addition, learning analytics practice can build upon prior work in LET standardization and innovation but there are several factors that require special attention. These factors include:

— requirements arising from the analytical process;

— data items required to drive operational LET systems are not always the same as desired for learning analytics;

— volume, velocity and variety of the data collected for analytics indicate different IT architectures, which imply different interoperability requirements;

— use of learner data for analytics introduces a range of ethical and other socio-cultural issues beyond those which arise from exchanging data between operational systems.

Therefore, this document gives a conceptual description of the behaviour of components related to learning analytics interoperability. In particular, this document specifies learning activity data interoperability which focuses on xAPI and IMS Caliper for the learning analytics process and interoperability.

Use cases will be collected to discover problems that arise in data transition points between heterogeneous learning data in schools, higher education and the workplace.

Information technology for learning, education and training — Learning analytics interoperability —

Part 3: Guidelines for data interoperability

1 Scope

This document specifies guidelines for mapping between different learning analytics data representations. Using xAPI and IMS Caliper as reference specifications, this document introduces data API regarding learning analytics as well as guidelines to use the APIs, which can be generalized to other contexts. Both syntactic and semantic mappings are in scope.

2 Normative references

There are no normative references in this document.

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— IEC Electropedia: available at http://www.electropedia.org/

— ISO Online browsing platform: available at http://www.iso.org/obp

3.1
assessment
means of measuring or evaluating learner understanding or competency

[SOURCE: ISO/IEC TR 20748-1:2016, 3.2]

3.2
dashboard
user interface based on predetermined reports, indicators and data fields, upon which the end user can apply filters and graphical display methods to answer predetermined business questions and which is suited to regular use with minimal training

[SOURCE: ISO TS 29585:2010, 3.3]

3.3
data analysis
systematic investigation of the data and their flow in a real or planned system

[SOURCE: ISO/IEC 2382:2015, 2122686]

3.4
data collection
process of bringing data together from one or more points for use in a computer

EXAMPLE To collect transactions generated at branch offices by a data network for use at a computer centre.

[SOURCE: ISO/IEC 2382:2015, 2122166]

3.5
data flow
movement of data through the active parts of a data processing system in the course of the performance of specific work

[SOURCE: ISO/IEC 2382:2015, 2121825]

3.6
data source
functional unit that provides data for transmission

[SOURCE: ISO/IEC 2382:2015, 2124348]

3.7
data storage
means for storing information from which data is submitted for delivery, or into which data is put by the delivery authority

[SOURCE: ISO/IEC 13888-1:2009, 3.7]

3.8
interoperability
capability to communicate, execute programs, or transfer data among various functional units in a manner that requires the user to have little or no knowledge of the unique characteristics of those units

[SOURCE: ISO TS 19101-2:2008, 4.17]

3.9
learning analytics
measurement, collection, analysis and reporting of data about learners and their contexts, for purposes of understanding and optimizing learning and the environments in which it occurs

[SOURCE: ISO/IEC 20748-1:2016, 3.11]

3.10
learning outcome
what a person is expected to know, understand or be able to do at the end of a training programme, course or module

[SOURCE: ISO/IEC 17027:2014, 2.57]

4 Abbreviated terms

API application programming interface

LET learning, education and training

LMS learning management system

LRS learning record store

LTI learning tools interoperability

VLE virtual learning environment

5 Introduction to data APIs for LET purposes

5.1 General

In general, many meaningful data are generated through a variety of learning activities using information and communication technology (ICT) in classrooms and/or online learning environments. However, at the end of such activities or processes, these data are usually discarded or partially extracted and recorded. For this reason, it is difficult to track what a learner has done and what skill level the learner has. This also makes it difficult to provide personalized learning environments (PLE) or to support adaptive learning. In many cases when this background information is missing, all learners are targeted to average levels, in terms of one-size-fits-all, and follow-up activities continue in situations where they do not comprehend a topic on their level of understanding. For example, in the physical environment for education, summative assessment data such as test scores are recorded manually but meaningful activity records are not accumulated in the learning processes. It is also difficult to provide personalized feedback for learning attitudes, preferences or cognitive levels, because it only measures the students' academic achievements through formalized tests. To overcome these limitations and to support and motivate individual learners, a new approach using data-based services known as *learning analytics* is being developed.

Systematic and accurate data collection is difficult due to diverse platforms and software used within learning environments. To address this problem, data profiles and/or data collection APIs for collecting learning data have been developed. However, different specifications for collecting learning data may cause institutions to use different data APIs among their heterogeneous learning platforms and software. There are two representative data profiles and APIs: Experience API (known as xAPI) and IMS Caliper, which allows for detailed data capture about learners' performance and learning activities/events in the LET domain.

Enabling data collection regarding learning activities, xAPI and IMS Caliper are introduced in this document as reference specifications for data APIs, and a comparison is done of the main features of the specifications and their implications for developing guidelines, which can be generalized into guidelines for data interoperability.

5.2 Experience API (xAPI)

According to the Advanced Distributed Learning Initiative (ADL), xAPI lets applications share data about human performance (broadly defined). More precisely, xAPI lets service providers capture (big) data on human performance, along with associated instructional content or performance context information (i.e., experience). xAPI applies “activity streams” to tracking data and provides sub-APIs to access and store information about state and content. This enables nearly dynamic tracking of activities from any platform or software system – from traditional learning management systems to mobile devices, simulations, wearables, physical beacons, and more.

xAPI can track micro-behaviours, state and context such as:

— reading an article or interacting with an eBook;

— watching a training video, stopping and starting it;

— training and behaviour data from a simulation;

— performance (user actions) in a mobile app;

— chatting with a mentor;

— physiological measures, such as heart-rate data;

— micro-interactions with e-learning content;

— team performance in a multi-player serious game;

— quiz scores and answer history by question;

— real-world performance in an operational context.

5.3 IMS Caliper

According to IMS Global, Caliper Analytics® attempts to address the underlying interoperability challenges in the learning technology landscape. Caliper provides an information model and a number of metric profiles, each of which models a learning activity or a supporting activity that helps facilitate learning. Each profile provides a domain-specific set of terms and concepts that application designers and developers can draw upon to describe common user interactions in a consistent manner using a shared vocabulary. Annotating reading materials, playing a video, taking a test, or grading an assignment submission represent a few examples of the many activities or events that Caliper's metric profiles attempt to describe.

IMS Caliper can track learning activities based on its profiles such as:

— Annotation profile: models activities related to the annotation of digital resources, such as creating a bookmark, highlighting selected text, sharing a resource, tagging a document and viewing an annotation.

— Assignable profile: models activities associated with digital content assigned to a learner for completion according to specific criteria.

— Assessment profile: models assessment-related activities including interactions with individual assessment items.

— Forum profile: models learners and others participating in online forum communities. Forums typically encompass one or more threads or topics to which members can subscribe, post messages and reply to other messages if a threaded discussion is permitted.

— Grading profile: models grading activities performed by an agent, typically a person or a software application.

— Media profile: models interactions between learners and rich content such as audio, images and video.

— Reading profile: models activities associated with navigating to and viewing textual content.

— Session profile: models the creation and subsequent termination of a user session established by a person interacting with a software application.

— Tool use profile: models an intended interaction between a user and a tool.

5.4 Brief comparison of xAPI and IMS Caliper

5.4.1 Context for the comparison

An initial comparison of the core features of the two specifications was developed in August 2016. The comparison of the core features of the two specifications was based upon:

a) Use cases, scenarios and motivations – identification and clarification of the original scope and context for xAPI and Caliper.

b) Service endpoints – identification of the types of data exchange that are supported and how this data is exchanged between the endpoints.

c) Data models – a comparison of the core data features, i.e., this analysis does not work down through the detailed data structures.

d) Security mechanisms – the data authentication, authorization and encryption mechanisms that are supported and/or preferred.

e) Transport mechanisms – the payload exchange technology, i.e., the ways in which the data definitions are physically exchanged across the networking technology.

f) Vocabularies, metric profiles, profiles and recipes – the mechanisms used to define the data vocabularies and the tailoring of the specification for specific application domains and use-cases.

g) Data science – identification of the actual learning analytics that can be created and the associated data science perspectives, e.g., statistical significance.

The key conclusions were:

a) Caliper and xAPI have very different origins. The core xAPI is to enable any type of experience and evidence tracking, both electronic and physical performance and not limited to just web-based courses (as is the case for SCORM). Caliper is the manifestation of the IMS learning analytics framework and the sensor API and profile(s) are the first two components of that framework. xAPI and Caliper are not equivalent. Adoption should not be 'one-or-the-other', instead it should be a decision as and where appropriate for specific needs.

b) While both xAPI (actor/verb/object) and Caliper (actor/action/activity) use a data model based upon a triple statement structure, there are considerable differences in the detailed structure and usage of the object and activity definitions. However, it should be possible for each specification to make use of the other's verb/action.

c) A formal processes for the definition and/or modification of the vocabularies, metrics profiles, profiles and recipes would need to be established with exemplars created to demonstrate the best practices when producing the corresponding documentation.

d) Any further work on either/both standards would need to include explicit participation of data scientists with knowledge of learning analytics. It needs to be ensured that the use of xAPI/Caliper can produce useful learning analytics information and not just data.

From a technology realization perspective, for a next generation, it would simplify common adoption and convergence to agree common payload binding (currently JSON against JSON-LD), a common security framework (currently OAuth 1 against APIkey), a common secure transport mechanism (currently HTTPS) and a common endpoint definition approach (including common agreement on the use of query parameters and URL construction).

Areas out-of-scope for the 2016 comparison were:

a) A detailed comparison of the approaches used by xAPI and Caliper for a specific use-case.

b) Establishing the scenarios for which xAPI or Caliper should be deployed.

c) Making decisions. This was purely an information-gathering exercise.

5.4.2 Detailed comparison

— Use cases / scenarios / motivations

xAPI features	Caliper features
The core use cases are: — To enable learning within the SCORM context and beyond-the-browser, outside of the LMS and outside of the SCORM package; — Distributed content: any type of learning content or experience can be delivered from a local computer, local network or on any remote servers; — Distributed data: learning data can be stored and shared across one or more systems; — Usage and performance data: paradata about learning resources that include not just quantitative metrics, but also pedagogic context, skills, and performance; — Team-based scenarios: data associated with users can now be aggregated and associated with a team or group of users; — Instructor/facilitator scenarios: instructor or facilitators may observe and send or receive feedback or annotations to users during a learning or performance activity using real-time data collection displayed in an interface or dashboard. — To provide system-to-system data transfer (including non-LRS based) that allows identification of data ownership, multi-agent statements, with an extensible data model and agnostic of security model.	The core usages are: — To enable the creation of quantitative metrics for learning; — To provide real-time data messaging to enable responsive learning engagement as opposed to just archive-based metrics; — To provide details on student engagement in learning activities; — To resolve the LTI/black-box conundrum. Caliper is IMS's learning analytics framework of which the sensor and metric profiles are just two components.

— Service endpoints

xAPI features	Caliper features
Supports both 'reading data from' and 'writing data to' an LRS. Explicit support for: — Statement API – create/read; — State API – CRUD; — Agent profile API – CRUD; — Activity profile API – CRUD; — About resource – read information about the endpoint.	The sensor API is used to write/post data to a Repository endpoint: — send () – to transmits event data; — describe () – to transit entity data. In version 1.x, Caliper does not support reading data from a data repository. EXAMPLE The sensor API is for writing data to a repository.

— Data models

xAPI features	Caliper features
The data model is based upon the statement and this {actor, verb, object} triple: — An actor is an agent or group (two or more agents); — There are four types of object, i.e., activity, agent, statement or sub-statement. statements can be composed of sub-statements; — The vocabulary for the verb, activity types and extensions are open. xAPI can be considered an 'activity scripting language'.	The data model is based upon the {actor, action, activity} triple: — The vocabulary for the action is controlled and constrained by the metric profiles. The data is exchanged either as a set of events or entities with an entity used to describe actors and activities. entities provide context for the events. each event is defined by a 'metric profile'. Events do not have explicit dependencies, i.e., they must be associated through the use of a session. Caliper can be considered an 'event scripting language'.

— Security mechanism

xAPI features	Caliper features
Support for: — Basic HTTP authentication; — Use of 2-legged and 3-legged OAuth 1.0 (with HMAC-SHA1, RSA-SHA1 and PLAINTEXT) for statement authorization. There is lot of information on authorization.	Use of API key. Use of HTTPS/TLS 1.3 is recommended to secure the message exchange. Very little discussion of security.

— Transport mechanism

xAPI features	Caliper features
The transport is HTTP/HTTPS with JSON payloads. Supports both the requestor (source) and the respondent (LRS) allocating the unique identifier for a Statement that is to be stored. Statements can be signed and the signature may also be stored in the LRS.	The transport is HTTP/HTTPS with JSON-LD payloads (note that the linked data aspects are not subject to conformance). The message is not signed. For conformance, IMS do not address the linked data aspects and treat the payload as formal JSON. There is a best practices recommendation for using LTI to provide the sensor endpoint and the corresponding API key.