A FLEXIBLE AND PERSONAL LEARNING ENVIRONMENT

FROM SINGLE COMPONENTS TO AN INTEGRATED DIGITAL LEARNING ENVIRONMENT: A SURVEY

SURF NET

CONTENTS

SUMMARY

The digital learning environment of the future must be flexible and personal. It must accommodate the needs and wishes of students and teachers, who want fast and easy access to information and materials, anytime and anywhere. This places great demands on institutions' ICT infrastructure, and sets high archival, security and administrative standards. The digital learning environment of the future will be an interconnected whole of services and applications that support students and teachers in their learning and teaching activities. This will also require innovative architectures, presenting a major challenge to the integration of these separate components.

This document describes the frameworks and components needed for a flexible and personal learning environment, as well as how these components can be integrated. It provides a frame of reference for further discussion, synchronisation and cooperation between institutions and suppliers.

THE DIGITAL LEARNING ENVIRONMENT OF THE FUTURE

The contours

A digital learning environment that focuses on the users (students, lecturers, departments) will benefit from **an architecture** in which user interaction, process support and data management are separate elements. This structure allows basic data to be accessed by multiple applications and transparent monitoring of the learning process. It also means that individual applications can easily be replaced or expanded and external user applications can be added. The digital learning environment facilitates the construction of **personalised learning pathways**, as well as multi-level and cross-institutional cooperation.

The components

There is no single application that can accommodate the needs and wishes of all students and teachers. The most obvious approach would seem to be a modular one in which all components (the services, applications and ICT systems used) can be easily joined together – like LEGO blocks – to form the entire learning environment. Components perform functions such as 'communication', 'collaboration', 'testing', scheduling and 'submitting and assessing assignments', and constitute the starting point when setting up a digital learning environment. Such components must be **interchangeable and expandable** so that the learning environment can always be adapted to the latest developments in education and incorporate technological innovations. Some available applications can be used in multiple components simultaneously, such as the all-in-one learning management system (LMS).

Standards and terminology

An interconnected whole made up of separate components that must appear to work as a single system is only possible by making technical agreements regarding the standards that the components must meet. Using standards allows data to be exchanged easily, safely and reliably. It is also important to agree on terminology, as various terms are often used to describe the same thing in the education sector.

The digital learning environment as an integrated whole

In practice, services and applications are never so standardised as to allow seamless compatibility. An **integration infrastructure** is required to enable separate components to function as a single system. An integration infrastructure allows for data to be exchanged between applications. There is a distinction between visual, data and system integration.

Visual integration

Visual integration provides a shell around all applications so that users feel as though they are working in a single environment. This can be achieved through portals or mobile applications that users can also use to create their own learning environments, and add or remove information or functionality.

Data integration

Data integration is about making the data from one application or source system accessible in other applications. This requires special interfaces such as Application Programming Interfaces (APIs).

System integration

Linking all of the separate systems together to form a single system requires a multitude of connections and is difficult to standardise and maintain. Specialised application integration software (such as an Enterprise Service Bus, or ESB) and a data warehouse allows systems to be interconnected. Such systems simplify communication between applications by converting the data from both the sending and receiving applications as necessary. Furthermore, they require only one connection to the ESB or data warehouse for each system.

Access to the digital learning environment

Portals and mobile apps are one way to personalise the digital learning environment. Access to the protected, underlying information and systems is organised by means of identification (who you are), authentication (whether you are who you claim to be) and authorisation (what information you are allowed to see). Authorisation grants users access to the services and data to which they are entitled, and can be based on either a user's assigned role within a project or organisation, or a certain group to which the student or staff member currently belongs. Effective group management is therefore essential. SURFconext provides functionality that enables the use of group information in a range of applications.

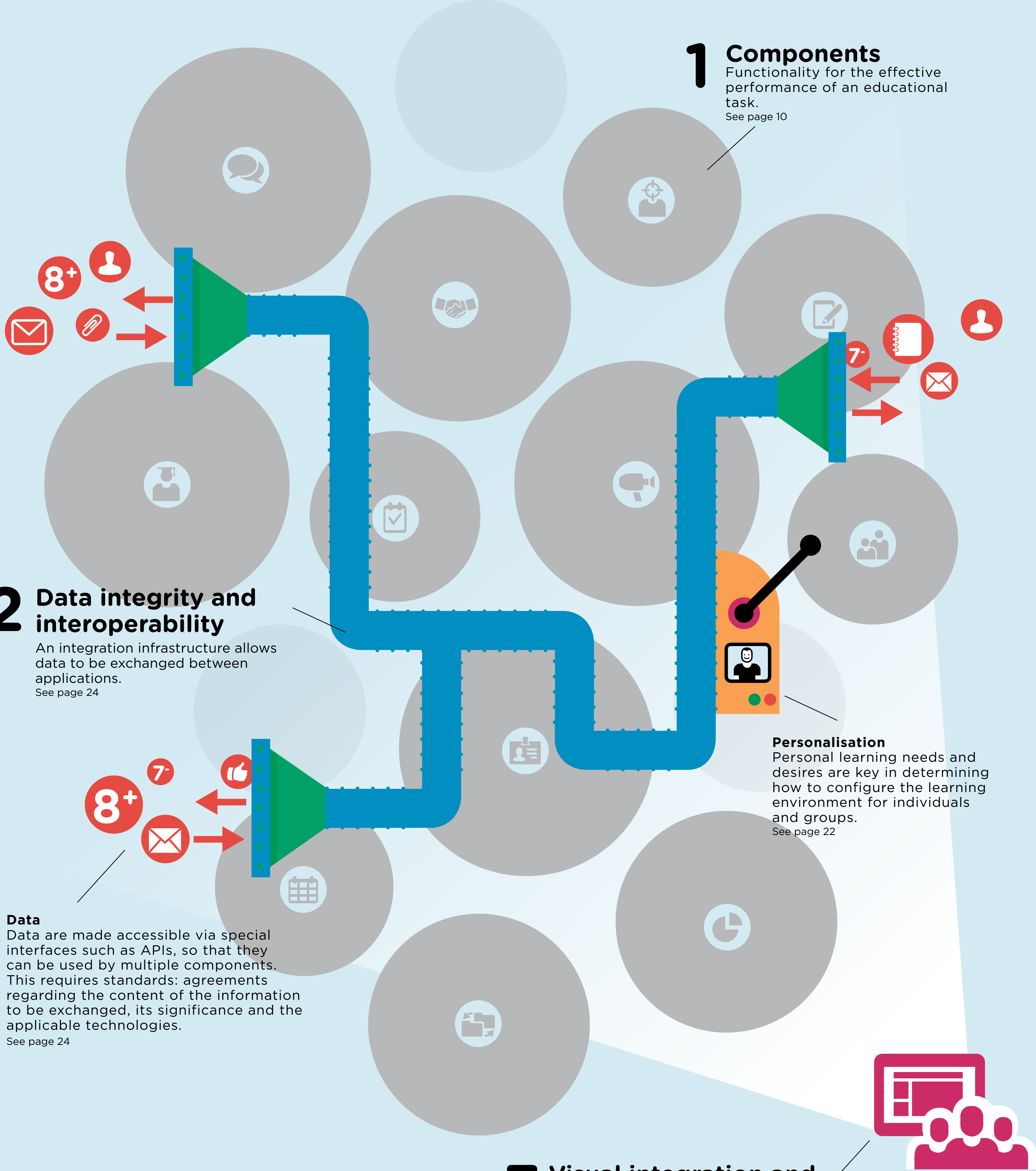
A future-proof digital learning environment

The development of a future-proof, integrated digital learning environment requires well-organised basic systems (such as the Student Information System, or SIS). It is also important to work on the basis of an architectural plan when integrating applications, particularly as the functionalities of many applications overlap. Standards and APIs are also important to enable the simplest possible integration of all components. Consideration must also be given to the governance of the digital learning environment and its acceptance within the institution.

The creation of an integrated learning environment that is in sync with developments in education, still needs a lot of work. Institutions will have to develop a vision of their own future digital learning environment in order to take the necessary action. Or, as the Educause report on the Next-Generation Digital Learning Environment states: *'The culture of higher education teaching and learning must evolve to encourage and even demand the realization of the Next-Generation Digital Learning Environment (NGDLE).'* Dutch higher education institutions now face the challenge of jointly tackling this problem. SURF is here to support higher education in this challenging innovation.

THE INTEGRATED LEARNING ENVIRONMENT

Exploring the options for a flexible and personal learning environment



1 Components

Functionality for the effective performance of an educational task.

See page 10

2 Data integrity and interoperability

An integration infrastructure allows data to be exchanged between applications.

See page 24

Personalisation

Personal learning needs and desires are key in determining how to configure the learning environment for individuals and groups.

See page 22

Data

Data are made accessible via special interfaces such as APIs, so that they can be used by multiple components. This requires standards: agreements regarding the content of the information to be exchanged, its significance and the applicable technologies.

See page 24

3 Visual integration and identity management

Users perceive the various components as a whole. Based on identity, group or role, people or groups are assigned user rights in certain components of the learning environment.

See pages 22 and 26

INTRODUCTION

Education is changing. Focus is shifting from teachers and classrooms and lecture halls to a form of education in which most of the initiative lies with the student. Many institutions are aiming to make their education more personal and flexible. In doing so, they seek to provide education that matches the learning needs of individual students as closely as possible.

High expectations

Students and teachers expect a lot from education and the digital learning environment. Often-voiced needs include access to information and materials anytime, anywhere, and a high degree of user-friendliness. At the same time, institutions place high demands on archiving, security and the manageability of infrastructure, presenting them with a major challenge.

The digital learning environment

According to our definition, a digital learning environment is 'an integrated collection of digital services and applications that supports students and teachers in their work'. Digital learning environments therefore always consist of multiple components. At many institutions, a learning management system (LMS) currently makes up the bulk of the digital learning environment. However, there is currently much discussion among both research universities and universities of applied sciences in the Netherlands regarding the future of the LMS, and its role in the digital learning environment. Institutions are searching for new digital architectures and components that are able to cater for the development and changing needs of education.

Components of the learning environment

What components will make up the next-generation digital learning environment? What components are needed to make a learning environment personal and flexible? And what is required for the integration of various components? What is already available, and what is not? To answer these questions, we present an overview of the components of a flexible and personal learning environment that are available through SURF or are being configured by institutions. We also look ahead to developments and components that will (or may) play a role in the not-too-distant future. This range of materials and products is not static and the overview provided here represents the state of affairs at the time of publication.

Collaboration between institutions

Because there are major differences not only in the current configuration of institutional learning environments, but also in governance and development processes, each institution has adopted its own approach, terminology and defined scope. This document sets out frameworks to facilitate synchronisation and collaboration and allow institutions to benefit as much as possible from one another's expertise. These frameworks are based on an environment constructed principally from modular components.

The context of this document

This document is one of the results from the 'Flexible and Personal Learning Environment' project, which is part of SURF's 'Customised Education'[1] *(Onderwijs op maat)* innovation programme and implemented by SURFnet in conjunction with SURFmarket and institutions. The project builds on the results of the 'Vision on Digital Learning and Working Environments' *(Visie op DLWO)*[2], an innovation programme completed by SURF in late 2014.
This document examines the possibilities for integrating components to create a flexible and personal learning environment. Its purpose is to give institutional staff involved in the development and innovation of digital learning environments an overview of the options available and of relevant sources of information.

1. Customised Education innovation programme: *https://www.surf.nl/en/innovationprojects/customised-education.html*
2. Vision on Digital Learning and Working Environments: *https://www.surf.nl/en/innovationprojects/customised-education/flexible-and-personal-learning-environment.html*

1. CONTOURS OF THE FLEXIBLE AND PERSONAL LEARNING ENVIRONMENT

This section provides an overview of the context surrounding the digital learning environment. What are the trends in education that make the focus on a flexible and personal learning environment so important? What exactly is meant by 'the digital learning environment', and what might these new learning environments look like? These are the questions that many institutions are currently grappling with.

Flexibility and personalisation as trends

Flexibility and personalisation are key trends in education. Personalised and flexible education is often based on the learner's personal learning needs and choices, rather than on a fixed curriculum. Many institutions are giving students greater influence over specific aspects of content, teaching methods, materials, assessment, time, place and the speed of their learning.

These trends are new, and nobody knows exactly how they will change education in the years ahead. It is therefore difficult to predict exactly what this means for the next-generation digital learning environment. Below, we give an overview of the possible implications.

Freedom of choice for teachers and students

With so many individual needs and wants, a personal and flexible approach is paramount in order to allow teachers and students (a relative degree of) freedom to use what they believe is necessary for the learning process. Because teachers and students are so central to developments in education, all stakeholders and user groups ought to be involved in the construction of the new learning environment.[3]

A transparent environment that makes the learning process visible

Personal learning pathways require a learning environment that supports student initiative, on the one hand, while making the learning process transparent and traceable for both teachers and students, on the other. This can be facilitated using tools such as digital testing, learning analytics and weblogs.[4]

Multi-level configuration

The NMC Horizon Report 2015[5] describes how personalised learning can be supported by a digital learning environment capable of being configured at the level of the individual (i.e. students and teachers), or of the institution, department or consortium. In addition to personal learning pathways, this also allows for the construction of pathways at various organisational levels (department, discipline, institute, etc.).

Integration of individual applications

Students and teachers do not limit themselves to using the applications and systems provided by institutions; they also use personal networks, social media and all manner of software and apps, including to support their learning/teaching. It is of great help to users if there is seamless compatibility between their own applications and those of their institution. Institutional schedule changes, for example, could then be automatically updated in students' and teachers' own calendars, and matters like personal cloud storage, social bookmarking, social media, personal blogs and Wikis could be incorporated in their own personal digital learning environments.

3. For more information on these developments, see: *http://www.jisc.ac.uk/guides/enhancing-the-digital-student-experience/deliver-a-robust-flexible-digital-environment*
4. Special edition on Didactics of Open and Online Education: *https://www.surf.nl/en/knowledge-base/2014/special-edition-on-didactics-of-open-and-online-education.html*
5. *http://www.nmc.org/publication/nmc-horizon-report-2015-higher-education-edition/*

Adaptive learning technologies
Personalised learning can also be supported through the use of adaptive learning technologies, with automated systems that coach students and give them suggestions customised specifically to their individual needs. Such adaptive solutions that effectively support personalisation using scientific and data-driven approaches (analytics) are a very recent development. Education can benefit greatly from these adaptive tools, for example for the provision of study materials and for assessments.

Adaptive progress testing in medicine
The feasibility of computer-controlled adaptive progress testing and its contribution to improvements in quality was demonstrated by the AdaPT project. An adaptive progress test was developed for students of medicine based on an item bank of multiple-choice questions used annually by the collaborating universities in Amsterdam (VU Amsterdam), Groningen, Leiden, Maastricht and Nijmegen.

The adaptive test presents students with a series of questions that are progressively tailored to their skill level. A customised, automatically generated test of this type can be administered at any time. The AdaPT[6] project demonstrated that catering to the individual student's level makes adaptive tests highly efficient as fewer questions are needed to get an idea of their progress.

Definitions of the learning environment
A flexible and personal learning environment is one that supports the trends described above. The exact contours of such an environment are not yet clear; developments in education in the years ahead will help to crystallise the design.

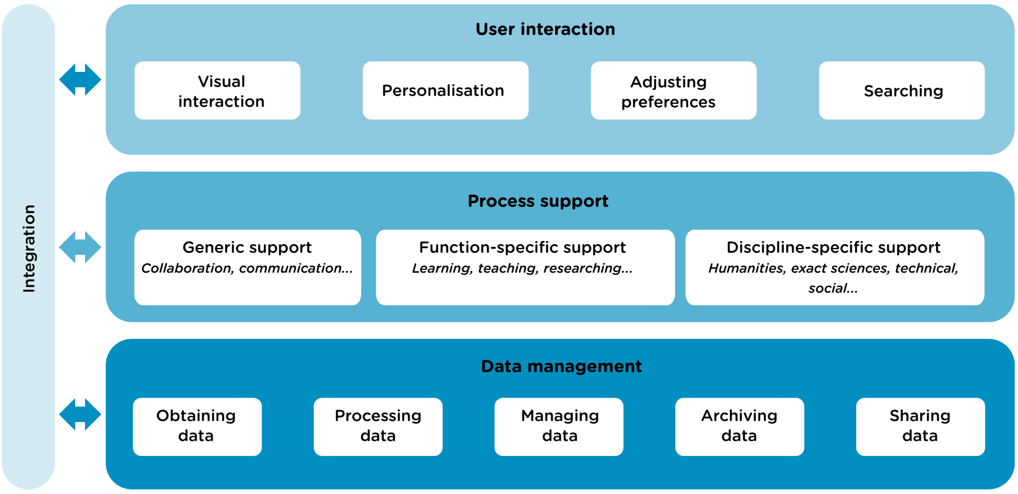
The digital learning environment
SURF defines a digital learning environment (DLO) as a collection of systems or applications that supports education and learning. Students and teachers use the digital learning environment for a range of education activities such as communication, the organisation of educational components, and exchanging content (assignments, notes, slides and information on schedules and marks). The digital learning environment is not a single system or application, but a constellation of digital services organised by an institution. This definition derives from the 2010 Digital Learning and Working Environment (DLWO) Advisory Report by the SURF Scientific Technical Council.

Many institutions also use alternative terms to refer to their digital learning environment, such as electronic learning environment, or e-learning environment and LMS (learning management system).[7]

Model for the digital learning environment
The model for the digital learning environment presented below distinguishes a range of components that are essential to any user-centred digital learning environment. The model describes an architecture that differentiates between interaction, process support and data management. This facilitates an integrated learning environment in which basic data can be accessed by multiple applications and in which applications can be replaced independently of each other.

This model forms part of the Higher Education Reference Architecture (Hoger Onderwijs Referentie Architectuur, or HORA, see the box on page 16) and provides insight into the functions of a digital learning environment at the ICT architectural level.[8]

6. More information about AdaPT: *https://www.surf.nl/kennisbank/2014/conclusies-en-resultaten-project-adapt-adaptieve-voortgangstoetsing.html*
7. For more information, see the glossary in the DLWO workbook: *www.surf.nl/werkboekdlwo*, and the box titled 'The scope of the LMS in the digital learning environment' *(De scope van het LMS binnen de digitale leeromgeving).*
8. A more detailed description of the model can be found in the DLWO digital workbook: *www.surf.nl/werkboekdlwo*.



Model for the digital learning environment

The digital learning environment of the future

The April 2015 Educause report titled 'The Next Generation Digital Learning Environment, A Report on Research'[9] outlines the contours of a digital learning environment for the future. According to the report, the five properties or options that a digital learning environment must provide are the following:

- The option to **integrate** tools and content and **exchange** educational data.
- The ability to construct both **personal learning pathways** and pathways at various organisational levels (faculty, institute, research group, etc.) Personalisation by means such as portals and role-based access.
- The ability to plan and advise on learning, based on educational data and **learning analytics**.
- The opportunity to **collaborate** at multiple levels and across institutions and to navigate between public and private digital spaces. Learning communities can then decide for themselves which parts of their learning environment to make public and which to keep private.
- The ability to create an **accessible** digital learning environment that embraces a more **universal design**, enabling it to be used by all parties without any modifications, and students to not only consume, but also produce and upload learning materials into the environment. Setting up portals will contribute to this aspect.

The Educause report points out a range of initiatives that that are shaping this vision of the next-generation digital learning environment, but also states that a lot of work is necessary in order to achieve it.

The following sections outline how the Netherlands is working to structure a flexible and personal learning environment that both supports learners in defining their own personal learning pathways and allows for customisation so that individual differences such as prior knowledge, personal learning goals and teacher/student preferences can be taken into account.

Such a digital learning environment requires an architecture that:

- is based on a model in which content and functionality are derived from multiple components *(Section 2)*;
- has interoperability standards *(Section 3)* to allow separate systems to work together.

9. Educause report, 'The Next Generation Digital Learning Environment, A Report on Research', April 2015 *http://net.educause.edu/ir/library/pdf/eli3035.pdf*

CASE STUDY: INHOLLAND UNIVERSITY OF APPLIED SCIENCES

ROADMAP FOR A PERSONAL AND FLEXIBLE LEARNING ENVIRONMENT

Inholland University of Applied Sciences is taking concrete steps to build an integrated learning environment, involving the creation of a roadmap and formulation of projects. SURFnet spoke to the university's IT architect Ton Gloudemans, application architect Mark de Jong and dot.net developer Arthur van Alten.

A digital learning environment that is personal and flexible

Inholland's current learning environment is complex. It incorporates a large number of applications and users often have trouble finding what they need. The institution wants to make its digital learning environment more accessible to users via a portal and to make it *more personal*. The envisaged portal will only show users information that is relevant to them. *Greater flexibility* will also be incorporated into the new learning environment, based on the belief that not all students should follow a fixed learning pathway. To help conceptualise the new digital learning environment, Inholland surveyed the educational requirements and the range of technical possibilities. Inholland wants to limit its approach to applications that are already on the market, but has found that market parties often want to provide a package solution. Where digital, integrated learning environments are concerned, institutions are better served by a series of specialist products that communicate effectively with each other. *'It's a complex matter and there is lots to think about, but ultimately it's easier for users and allows for more effective management'*, say the ICT specialists at Inholland.

Core components: the portal, APIs and the data vault

The portal plays an important role in the concept at Inholland: it is the 'shell' that will wrap around the entire learning environment. All user-relevant information will be displayed in one place, but the information will be sourced from different systems and not stored in the portal itself. All systems must ultimately be able to feed this portal with information. A mock-up of the My Inholland dashboard has been created, organised into menu blocks such as Calendar, Schedule, Marks and News to which information is pushed. This way, users only get access to their own schedules and marks. The portal will also offer a clear directory of all the various components (an A-Z) and a good search engine. Application Programming Interfaces (APIs) are essential to the connection and integration of applications. Each individual application or tool to be integrated must therefore have an API and the functionality to exchange information. The question still remains whether all the applications currently used by students and teachers will be integrated; each application will be assessed separately to determine whether integration is possible and/or necessary. In addition to the portal and APIs, a data vault is another important component of Inholland's digital learning environment architecture. Data vaults are specifically designed to store data from various sources, with varying definitions and levels of reliability. Each data item is stored with a number of additional parameters so that it is always clear where it has come from and when it was created.

Challenges: LMS, learning analytics and groups

The role that the current learning management system (LMS) will play in the integrated digital learning environment has not been crystallised yet. Will it continue to play a key role, or not? After all, when a basic LMS grows (too) empty, it has little more to offer the institution. Learning analytics is another challenge. Although pilots have been conducted at Inholland, learning analytics still plays no part in the learning process. Inholland does see potential ways to implement it, however, such as in self-study or feedback tools. But for the time being there is still no effective instrument available and it remains unclear which analyses are useful to the learning process. Support for groups constitutes another key challenge. Integration at different levels remains particularly tricky (such as a group of first years with a third-year mentor). Inholland is currently in talks with SURFnet to examine whether SURFconext Teams might offer a possible solution in this regard, and is considering a variety of approaches to how matters such as authentication, authorisation and groups can be coordinated with SURF and other institutions. *'We'll lay the foundations over the next six months. Then things will get exciting – when we do the actual integration'*, say the Inholland ICT staff. Inholland wants its digital learning and working environment (DLWO) to be in place by 2018; should it be any later, current ideas will already be outdated. Though there are still concerns about whether there are enough capacity and expertise to bring the project to completion, the motto is 'just do it', because an institution has to be prepared for the unforeseeable changes that lie ahead.

2. COMPONENTS OF THE LEARNING ENVIRONMENT

The next-generation digital learning environment will consist of a variety of (often pre-existing) components that students and teachers can use as needed. Some components will be available to all students and teachers at an institution, and others will not. The components must also be interchangeable and expandable, so that the learning environment can always be adapted to the latest developments in education and to technological innovations.

The LEGO approach

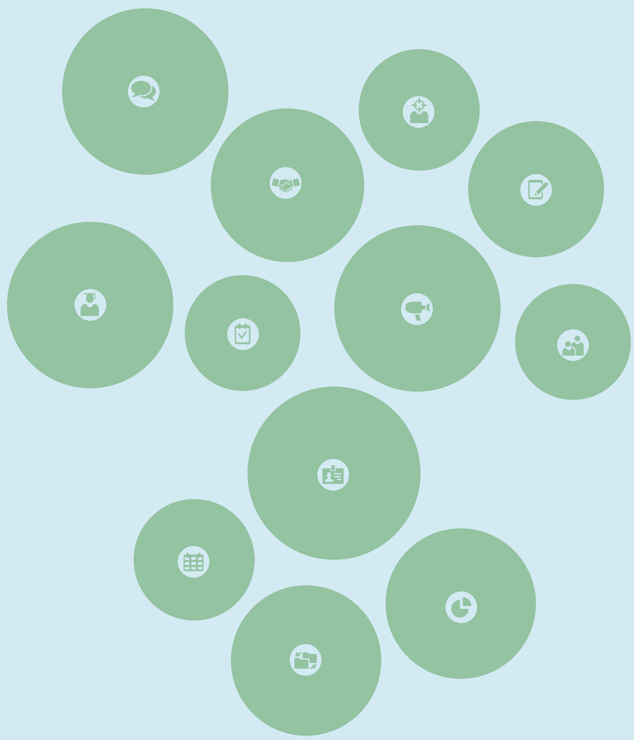
This modular approach aligns with the developments sketched in the April 2015 Educause report, which conceives of a constellation of LEGO blocks that together make up the learning environment. Because there is no single system that can meet the needs of all teachers and students, it makes no sense to try to build one that does. We must therefore start thinking about how all the (often pre-existing) 'LEGO blocks' can be interconnected with each other. LEGO blocks can be used to build a wide array of constructions, from a simple tower to an entire city. The same will need to apply to the individual components of the digital learning environment so that they join up properly.

Of course, you can do this with LEGO because all of the blocks are designed to fit together. There are many different types of components that can be joined in endless combinations and they all fit together perfectly. Analogously, the components of the learning environment will have to be governed by agreements regarding their design, in the form of standards. These standards will define the technical requirements that all components must meet – Section 3 discusses this aspect in greater detail.

Components

Components provide functionality for the effective performance of an education task. Here, functionality refers to 'the entirety of possible applications' (i.e. functions).

Applications available on the market or developed by institutions themselves often provide functionality for many different tasks. One example is a learning management system (LMS), which provides functionality for communication, collaboration, testing, organising content and so forth. These systems are often referred to as 'all-in-one' or 'container' applications.



The components of the digital learning environment

This document uses the term ‘component’ to denote the specific functional elements that can be used to construct the digital learning environment. These components have been classified in a way that will be familiar to the education sector, following the ‘education application model’, which is one of the reference models in the Higher Education Reference Architecture (see box on page 16). The functionalities of applications within this model were therefore assessed and the components classified accordingly. Some components are described at a higher level of abstraction than the applications. For example, the plagiarism detection system is classed under the ‘submitting and assessing assignments’ component. Components have also been added that are important from an education standpoint, but that are not (or not yet) included in the HORA, such as the learning analytics component.

Obviously, this classification is open to discussion as the potential applications of components are not mutually exclusive; the functionality of one component may also be relevant to other components. ‘Communication’ and ‘presenting content’, for example, are important aspects of multiple components.

It is also important to realise that the available range of services and applications is not static: new services and applications are always being released, and others discontinued. Also, components are subject to change as education itself changes.

Below we provide a description of the significance of each component and exactly what it entails, followed by an explanation of the relationship between the components, the model for the digital learning environment and the applications.

Component: Communication

Communication is an essential part of all types of education and involves sending messages and information and starting dialogues. For teachers, it is important to be able to contact entire groups of students at once. It must also be possible to communicate with students, colleagues and other contacts one-on-one. Students have to be able to get in touch with teachers, supervisors, fellow students and other contacts. Likewise, departments, faculties and institutions need to be able to send information to students and student groups.

Component: Collaboration

Collaboration in education is becoming increasingly important as it enriches and enables greater depth of learning. A digital learning environment must therefore offer enough opportunities to facilitate collaboration of all kinds. Examples include cross-institutional collaboration, remote collaboration on documents, the mutual provision and evaluation of feedback, and the shared discovery and use of content from outside the institution.
Joint learning as part of MOOCs and other learning communities must also be possible, requiring effective group management.

Component: Organisation of learning

The ‘organisation of learning’ (or: learning management) is about making sure students have clear and easy access to the correct content and applications they need for their studies. This includes functionalities such as assigning students to groups, assigning students (or groups of students) to courses and arranging access management (see also the ‘Services and applications via SURFconext’ box on page 16). The organisation of learning is a key aspect of learning management systems (see also ‘The scope of the LMS within the digital learning environment’ on page 12).

The scope of the LMS within the digital learning environment

A learning management system (LMS) generally includes functionality for a variety of different tasks. There is currently much discussion between Dutch research universities and universities of applied sciences regarding the future of the LMS and its scope in the digital learning environment.

An article by Gartner[10] describes how the LMS is progressively evolving from a closed into an open platform with options for the integration of other tools. This concept assigns the LMS the role of a basic system in the learning environment that other tools can be 'plugged into'. An article by Educause[11] sketches the contours of a next-generation digital learning environment that does not necessarily rely on an underlying LMS. Both articles emphasise that integration and interoperability are essential to the learning environments of the future.

Although a number of Dutch universities have expressed the need for an underlying LMS, as yet there is no consensus on exactly what this fundamental layer should contain. Some seeks functionalities such as those described here under 'organisation of learning', alongside the basic 'communication', 'collaboration' and 'presenting learning materials' functionalities. Other institutions are only concerned with functionalities akin to 'middle-ware' – with connecting groups of applications and content. The discussion is further complicated by the fact that there is currently no good example of a basic LMS and that the possibilities for integration and interoperability are still under development.

Component: Testing

The SURF programme on 'Testing and Test-based Learning' (2010-2015)[12] has shown that digital testing can improve the quality of learning and testing in education. Within the 'testing' component we could also differentiate between four subcomponents: an author environment, a playback environment, an analysis tool and an item bank.[13] Crucially, the digital learning environment will have to support various testing methods.[14] The testing component must be set up in such a way that a distinction can be drawn between summative testing, meaning tests resulting in a formal assessment, and formative testing, which is about collecting information on students' progress in order to subsequently adjust their learning process.

Component: Internships and final projects

Internships and final projects are a part of all degree programmes in the Netherlands. The 'internships and final projects' component provides the functionality for evaluating the match between the internship/final assignment, the host organisation and the student. Other internship functionality must also be included, such as contract and document management, progress monitoring and relationship management.

Component: Submission and assessment of assignments

Assignment submission functionality is key within any learning environment, which can be provided by an upload tool, for example. This component must also include functionalities for managing the submission and evaluation process such as setting and communicating deadlines (approaching deadline alerts, automatic inclusion of deadlines in student calendars) allocating first and second assessors, coordination between assessors, providing student feedback, awarding marks, assessment notifications and the option for students to appeal decisions. One indispensable application for checking assignments is plagiarism detection. Many faculties use tools to automatically check students' work for plagiarism. Students themselves are sometimes also able to perform plagiarism checks to verify whether they have referenced their assignments properly and whether fellow students with whom they have collaborated have done so as well.

10. Morgan, G. (July 2015). How to Establish a Learning Eco System with LMS Platforms. *www.gartner.com/doc/3088117?ref=AnalystProfile&srcId=1-4554397745*
11. Brown, M., Dehoney, J. & Millichap, N. (April 2015). The Next Generation Digital Learning Environment, A Report on Research. *http://net.educause.edu/ir/library/pdf/eli3035.pdf*
12. Digital testing: *www.surf.nl/toetsen*
13. Digital assessment terminology, SURF knowledge bank *https://www.surf.nl/en/knowledge-base/2013/digital-test-terminology.html*
14. For more information, see page 7 of the Educause report: *http://net.educause.edu/ir/library/pdf/eli3035.pdf*

Component: Video

Video is playing an increasingly important role in education, due in part to developments such as the ‘flipped classroom’, in which the initial knowledge transfer takes place outside the classroom (e.g. via recorded lectures). Video uplinks sometimes allow lectures to be attended remotely in real time. Students themselves also create video footage for assignments or to demonstrate their progress. This component must include functionality for recording, real-time display, on-demand playback, editing, saving and management of video footage.

Component: Education process support

Education process support concerns tools used for monitoring students’ progress and giving them targeted feedback to support their learning process. Interviews with students regarding next-generation learning environments[15] have revealed that they are assessed on their final products too much and not enough on their learning process. This approach can be particularly counter-productive when it comes to group assignments completed with other students, when it can be very tempting to divide the work so that each student plays to their own strengths, ultimately reducing the opportunities for learning. Many institutions work with digital portfolios that are intended to promote student learning by monitoring their development, providing feedback and gathering materials (often by students themselves) to demonstrate it. The April 2015 Educause report discusses the need for a ‘Portfolio 3.0’: a set of applications and platforms that offer students a range of integrated portfolio solutions for displaying all of their completed work and experience gained in a single overview.
A pilot study[16] at the Faculty of Veterinary Science at Utrecht University experimented with remote coaching, focusing on functionalities such as providing live feedback via video uplinks and quick access to learning materials (such as instructional videos) and compiling video materials and feedback in a portfolio.

Component: Management and use of student information

The ‘management and use of student information’ component involves both the management of administrative student data (e.g. personal details) and the registration of marks, progress and attendance. An integrated digital learning environment requires basic data – i.e. the registration of student details, progress data and even schedule information – to be well-organised, meaning stored and managed according to a fixed standard. Only then will it be accessible from multiple applications.

Component: Timetabling

In essence, timetabling is about reaching the best possible distribution of time and resources across teachers and students. Flexible and personalised education changes the requirements in this respect, due to an increase in demand-driven learning and in diverse and personalised learning pathways. Responding effectively to these changes represents a challenge to institutions.

Component: Developing, managing and sharing learning materials

There can be no education without learning resources, which may consist of texts, images, tests and audio and video material. This component concerns functionalities for the development, management and sharing of learning materials.

Development of learning materials

Learning materials may be developed by educational publishers, but also by education institutions themselves. In that case, developers need tools to enable them to create these materials. In addition to specialised authoring tools, common programs used to produce teaching materials also include word processing and presentation tools. Educational publishers are focusing more and more on the development of digital resources. In its eStudybooks pilot, SURFmarket is investigating whether it can play a part in providing digital learning materials in order to ensure teachers and students always get the best deal.

15. Den Hartogh, C. (2015). Design Thinking at SURFnet: An Inquiry into Student Perspectives on Digital Learning Environments. See: *http://www.scriptiesonline.uba.uva.nl*.
16. See also the best practices of the Faculty of Veterinary Science at Utrecht University: *https://www.surf.nl/binaries/content/assets/surf/nl/kennisbank/2014/bestpractice_4g_uu_diergeneeskunde_.pdf*

eStudybooks pilot
SURF wants to examine whether it can play a role in offering digital coursebooks to students and lecturers in higher education. In 2015, two pilot programmes will be prepared for the flexible provision of digital content. The first pilot focuses on offering digital content for purchase or rent to individual students. The second pilot is based on a subscription model and gives students access to all the relevant titles they need for a monthly fee. Both pilot programmes will launch on 1 September 2016 and will serve as the basis for determining how to provide institutions, students and lecturers with the best deal.
The pilots will use Bookshelf, a distribution platform for educational e-books, and examine the possibility of integrating Bookshelf's functionality into the digital learning environment.

Storage and management of learning resources
Once learning materials have been developed, they need to be stored and managed. Ideally, the method chosen makes it clear to everybody where to find the latest version of each document. To enable the exchange and re-use of learning materials, it is important that they are tagged using standardised metadata.

SURFdrive
SURFnet offers secure storage for the Dutch education and research sector in the form of a personal cloud storage service called SURFdrive.[17]

In a pilot at Utrecht University, students developed a storage component suitable for next-generation learning environments. This component enables users to work with documents within the learning environment no matter where the documents are stored. The pilot was carried out using Dropbox, Google Drive and SURFdrive. See page 32 for more information and details of the project.

Sharing learning materials
Many institutions are keen to share learning materials with users within (and outside) their own walls. Repositories offer a very good way to share learning materials. As digital storehouses where materials can be saved using metadata that meet international data-exchange standards, they enable higher education institutions to make their collections of (both open and closed) learning resources (and research results) available internally and externally.[18]
Institutions may store materials in their own repositories, or use a shared repository. One example of a shared repository is Sharekit, a service developed by SURF to facilitate the exchange of knowledge products generated by universities of applied sciences.

Component: Learning analytics
The learning analytics component concerns applications that collect and analyse information on students' learning process in order to gain insight into and improve teaching and learning processes. This includes applications that can collect, save and analyse data, and applications that can visualise and present these analyses.
Various components of the digital learning environment collect student data, and this has to be standardised in order to allow analysis and interpretation. As learning analytics are necessary to facilitate personalisation and personal learning pathways, the ability of all components to provide standardised data will be essential to education in the future.

17. SURFdrive: *www.surfdrive.nl.*
18. Read more about the development of open and online education: *https://www.surf.nl/en/innovationprojects/customised-education/open-and-online-education.html*

Learning analytics and big data
Because the current tendency among students is to roam in and out of multiple systems, it is still uncertain whether learning analytics present the right way to gather their personal data. Learning no longer occurs exclusively inside institutions but also, and to an increasing extent, outside them. All information provided online contributes to students' learning process – reading a Wikipedia page or watching a YouTube video on a certain topic can provide insights that significantly advance the learning process. The question is whether linked learning analytics systems can provide sufficient information on their own.
Players such as Google and Facebook (which collect big data and use it to conduct analyses and make predictions) rely not only on their own systems but spread themselves out across the Internet. The question is whether learning analytics should follow their example and – like Google Analytics – generate a complete picture of all user activities. This also raises the question of whether learning analytics should be applied using a limited set of systems, when much (if not all) information about students is already available from a wide range of other Internet systems. Further research could help determine which other forms of big data and analysis could be useful.[19]

Components in relation to applications

As mentioned previously, the functionalities of components overlap. For each component, the table below provides examples of applications offering process support (layer 2 in the digital learning environment model on page 8) and data management functionality (layer 3 in the model). The purpose of this overview is to clarify where overlapping functionalities exist and how applications can be organised accordingly.

Component	Process support	Data management
Communication	• Email program • Author environment for web content	• Email archive • Web content management system
Collaboration	• Collaboration systems • Wikis • Discussion boards	• Archive of discussions and collaboration sessions
Organisation of learning	• Group management tool • Presentation tools	• Document management
Testing	• Author environment • Playback environment • Analysis tool	• Item bank
Internships and final projects	• Tool for matching supply and demand • Progress monitoring tools	• Relationship management • Document and contract management
Submission and assessment of assignments	• Upload tool • Plagiarism detection tool	• Document management
Video	• Video editing tools • Video streaming system	• Video management system
Education process support	• Feedback tools • Peer feedback system • Communication tools (see component 1) • Digital portfolio (uploading/authoring tool)	• Feedback archive • Document management • Digital portfolio (document management)
Management and use of student information	• Tool for registering results • Attendance registration tool	• Student information system • Document management
Timetabling	• Scheduling application	
Developing, managing and sharing learning materials	• Content creation tools • Publication platforms • Content playback programmes	• Content storage system • Repository • Referatory • Document management
Learning analytics	• Learning analytics processor	• Learning records warehouse

19. From: Learning Analytics, SURFconext & the Open Education API: A technological exploration (report available from SURFnet on request).

The components in level 1 of the digital learning environment model (user interaction) are described in Section 3. Discipline-specific support in layer 2 is not included here either because, as the name suggests, the layer is specific to each discipline. These layers may include applications such as design software for technical degree programmes, financial packages for business programmes and simulation tools for medical programmes.

Services and applications via SURFconext

SURFconext[20] was developed to support both intra- and inter-institutional collaboration. SURFconext users only have to log in once with their institutional account to safely access a large number of services. These services integrate seamlessly with the existing online environment at their own institutions. The cloud-services available through SURFconext are commercial services and institutional services.[21]

Freely available applications

In addition to the applications and systems provided by institutions, students and teachers also use social media, software and apps in their learning process, including apps they create themselves. Institutions can take advantage of this by facilitating the ongoing addition of new tools to their digital learning environment, requiring them to place a specific focus on the integration of these types of applications. Some institutions choose to assess applications individually to determine if they should be integrated into the learning environment.

Higher Education Reference Architecture (HORA)

The HORA[22] is a reference architecture specific to the higher education sector. Institutions can use the HORA as a guide for their own organisational structure and information management. It is made up of three parts: the architectural concept, reference models and implementation resources.

The HORA was designed by university IT architects in collaboration with SURF and is managed by the higher education architects consultation platform ('Architectenberaad HO'), which is currently working to develop the teaching component in various models.

20. *https://www.surf.nl/en/services-and-products/surfconext/index.html*
21. An up-to-date overview of all available services and applications can be found at: *https://www.surf.nl/en/services-and-products/surfconext/cloud-services-connected-to-surfconext/index.html*
22. For more information on the HORA, see: *www.wikixl.nl/wiki/hora*.

CASE STUDY: ERASMUS UNIVERSITY ROTTERDAM

CONCEPTUALISING AN INTEGRATED LEARNING ENVIRONMENT

SURFnet spoke to Marieke Veenstra, Wilco te Winkel, Sebastiaan Kamp and Chris Tils from Erasmus University Rotterdam (EUR) about the university's plans for a digital learning environment.

All digital services in one place

The current situation at the university is complex because faculties have set up their own learning environments. Also, the outside world is exerting an increasing influence on the university (a trend among higher education institutions generally), as a result of collaboration with companies, alumni who remain affiliated with the university, and students who want to personalise their programmes through cross-institutional study. EUR is therefore looking for a new way to structure a digital learning environment for the entire university that gathers all digital services in one place.

Prerequisite: basic systems in order

An important prerequisite for the development of an integrated learning environment is that all the basic systems, such as the Student Information System (SIS), are properly organised. EUR has been working on this requirement in recent years and is now ready to take the next steps.

Personalisation and integration

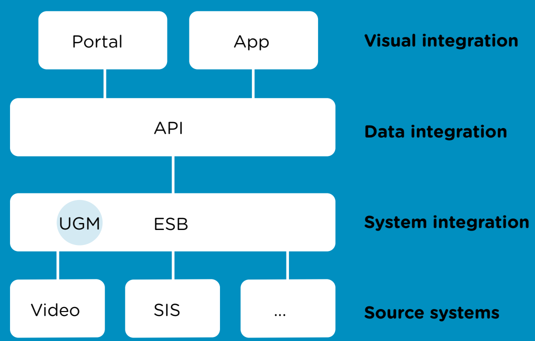
EUR wants to offer personalised information and services to the users (i.e. students and lecturers) of its digital environment. To ascertain which functionalities and services students need, a list of 'top tasks' was created: 29 tasks that students want to carry out using the digital learning environment. Faculties currently use a variety of systems as learning environments. The first services to be integrated into the digital learning environment should be those used by practically all faculties. A single basic system will be used for each functionality, which is now possible thanks to the work conducted in previous years. There still has to be scope at each faculty for innovation in the development or use of new applications at each faculty, however, and whenever such applications also offer functionality to all or most of the other faculties, integration into the new digital learning environment must be possible.

Challenge: capacity and governance

EUR aims to found its future digital learning environment on a modular approach. But can they pull it off? After all, getting an integrated learning environment up and running effectively requires sufficient capacity. Another priority is governance. EUR, probably like many other institutions, has no experience of managing a modular system. And who should take on which tasks? A modular approach will require the university to define more parameters for the integration of new services and applications, and to draw clear distinctions between ownership of systems and ownership of data.

Architecture

In the architecture of the digital learning environment, EUR draws a distinction between data integration, system integration and visual integration (in which apps and the portal (Liferay) play a part). The portal is a shell that displays students' 'top tasks'; it is the initial, central starting point from which students access all of their digital services. Data integration is facilitated using an Application Programming Interface (API) optimised for web applications (such as portals and apps). Instead of the data format used by the source systems (such as the SIS), the API uses the generic University Data Model (*Universitair Gegevens Model,* UGM), as converted by the ESB (Enterprise Service Bus). EUR will start by making Osiris available in this manner. The UGM provides EUR with uniform data definitions of the key information elements or concepts that can be used for teaching or operational purposes, as well as an understanding of how these elements relate to one another.



Architecture

EUR has set up an ESB team, and the application development team is in charge of the API layer. EUR is also involving architects and ICT in the system's development in order to ensure a workable environment.

Challenge: University Data Model (UGM)

The UGM is still something of a contentious issue for EUR, mainly because it is still incomplete. It is not yet clear exactly which data requires exchanging, and lots more work is still required to complete the basic model. A joint approach is deemed desirable as the issue is practically the same for all institutions.

An ongoing project

Although EUR will continue to refine and develop its concept of the integrated learning environment, those involved realise that the project will be ongoing: *'Institutions are preparing for the flexible future, but of course we will never get there. Students change, and the future is impossible to predict. There are some things institutions can take ownership of, such as operational matters, registration of results, scheduling and student data. The foundation must be solidly structured and organised. Then you'll be ready for what the future brings.'*

3. INTEGRATION, ACCESSIBILITY AND PERSONALISATION

In addition to their integration and interoperability requirements, next-generation learning environments must also be accessible and provide options for personalisation. This section discusses solutions that support these features: standards, various forms of integration and options for identification, authentication and authorisation.

3.1 STANDARDS

Digital learning environments are made up of a variety of components, such as for assessment, communication and timetabling. The greatest challenge is to get all of the applications and IT systems used in these components to work together. Standards for interoperability (mutual compatibility of separate systems) are therefore crucial.

What are standards?
Although the world is using ICT more and more for collaboration and communication purposes, not everybody uses the same software. And yet, MacBook users have no trouble sending messages from their email program to a Windows laptop that uses Outlook.

Interoperability allows for improved compatibility between different systems, and makes it easier to share data. Doing so requires agreements on the content of the information to be exchanged, its significance and the applicable technologies. Such agreements are sometimes made between two organisations, but more often they apply to an entire sector or a certain generic type of application. In the latter case, they are called standards.

Standards exist in the form of agreements, concepts and architectures. Open standards are not supplier-dependent (or 'proprietary') but foster integration and exchange between facilities. Using standards enables data to be exchanged simply, securely and reliably, which benefits the quality of the exchange. It is also more economical and efficient to create and maintain a single interface and to avoid supplier dependence.[23]

Reaping the full benefits of standards requires widespread adoption; applications can only be interfaced simply if as many parties as possible keep to the standards. The adoption of standards is a major challenge and an ongoing process, and the education sector is no exception. There are parties at both national and international level that encourage and drive the adoption of standards, such as the IMS Global Learning Consortium, ISO/NEN, IEEE, the Standardisation Forum (Forum Standaardisatie) and Bureau Edustandaard.

Who creates and manages standards?
A relatively large number of education standards are developed and managed internationally by the IMS Global Learning Consortium, a non-profit organisation with members from various countries, including Blackboard and – from the Netherlands – the Tests and Examinations Board and SURF. Another standards organisation operating internationally is Advanced Distributed Learning (ADL), founded by the American government.

23. See the report titled: 'Developments in the digital learning and work environment in higher education' (Ontwikkelingen in de digitale leer- en werkomgeving van het hoger onderwijs), SURF, 2012. *https://www.surf.nl/en/knowledge-base/2013/developments-in-the-digital-learning-and-working-environment-in-higher-education.html*

On a national level, the Netherlands Standardisation Institute (NEN) represents the Netherlands in the ISO (the International Organisation for Standardisation) which actively moderates standards, and the ICT and Learning Technologies committee (commissie ICT en Leertechnologie) also works on education standards.[24]

In 2006, the Dutch government launched the Standardisation Board and Standardisation Forum (College en Forum Standaardisatie) in order to promote interoperability and the use of open standards. The core of the government's open-standard policy is based on the 'comply or explain' principle, which requires government authorities and public-sector organisations to apply the relevant open standards in the list issued by the Standardisation Forum when developing, purchasing or outsourcing ICT systems and services (to a value greater than €50,000),[25] or otherwise explain why they have not done so in their annual report. This policy applies to the entire public sector, which consists of all public and semi-public organisations as well as the health and education sectors.

Edustandaard, a partnership between SURF and Kennisnet, is responsible for managing and advising on education and research-specific standards and reference architectures throughout the entire education and research sector.[26]

Agreements, terminology and architectures

Within the higher education sector, the HORA (Higher Education Reference Architecture) is an important architecture and is described in Section 2 (see box on page 16).

The education sector is working on the more efficient and uniform provision of information (including across sectors). The Education Sector Reference Architecture (*Referentie Onderwijs Sector Architectuur*, ROSA) is the reference architecture for education and an instrument used in information-based collaboration throughout the sector. The six sector councils have joined together under the Education Information Collaboration Platform (Samenwerkingsplatform Informatie Onderwijs, SION), which is collaborating on the ROSA with the Education Implementation Service (Dienst Uitvoering Onderwijs, DUO) and the Ministry of Education, Culture and Science (OCW). ROSA is an instrument that provides frameworks for converting the joint goals of the education councils, the Ministry and DUO into ICT projects throughout the sector. It also provides insight into, and creates cohesion among, existing and future facilities. The ROSA is a resource for all those in education who are involved in information exchange, such as project leaders, policy developers, administrators, education managers and technicians.

The HORA is managed by the Higher Education Architects Consultation Platform (Architectenberaad HO). For the time being, the ROSA is managed by the SION, but from 1 January 2016, its management will probably be delegated to Edustandaard, where both architectures are registered.[27]

Terminology

Agreements on terminology are also important to interoperability. Different education sectors each have their own processes and legislation, and the variation in terminology used to describe the same information often complicates cross-sector exchange. In the Netherlands, for example, those enrolled in primary education are called 'pupils' (*leerling*), while in higher education they are called 'students' (*student*). This linguistic confusion is thrown into sharper relief by the digital exchange of information. How does a computer system know that 'language' means the same thing as 'Dutch', but only within the context of the education sector? Setting out fixed terms and definitions makes it clear when people are talking about the same thing. Edustandaard lists these terms in the Education Terminology Framework (*Onderwijsbegrippenkader*, OBK), a shared online database that lists all education terms and how they are interconnected.

The Core Education Information Model (*Kernmodel Onderwijsinformatie*, KOI)[28] is also relevant with regard to terminology frameworks, as it enables cross-sector data exchange among education organisations. The KOI currently mainly targets primary, secondary and senior secondary vocational education, but may also offer handholds for higher education.

24. See also the relevant NEN standards and committees: https://www.nen.nl/Normontwikkeling/energy/Leertechnologieen.htm, and ISO, http://www.iso.org/iso/iso_technical_committee%3Fcommid%3D45392
25. List of open standards: *https://www.forumstandaardisatie.nl/english/*
26. More information on standards: *http://www.edustandaard.nl/, http://www.imsglobal.org, http://adlnet.gov/*
27. Higher Education Reference Architecture (HORA): *http://www.wikixl.nl/wiki/hora/index.php/Hoofdpagina*, Education Sector Reference Architecture (ROSA): *http://www.edustandaard.nl/standaarden/architecturen/architectuur/rosa/3.0/*
28. Core Education Information Model (KOI) terminology set: *https://www.edustandaard.nl/standaarden/begrippen/begrip/begrippenset-kernmodel-onderwijs-informatie-koi/1.1/*

Next year, Edustandaard will work on applying the KOI to higher education. Terminology frameworks also exist for online education, digital learning environments and digital testing, which describe relevant concepts with the aim of improving communication about these matters.[29]

Agreements
This document focuses primarily on agreements that contribute to the integration of and exchanges between the components of digital learning environments as described above. The legal standards framework is also a set of agreements (i.e. standards), but at a legislative level. It outlines the confidentiality, privacy, property and availability standards that cloud suppliers' products must meet in the higher education sector.[30]

What are the relevant standards?

Below we provide as comprehensive an overview as possible of the standards relevant to digital learning environments, with references to the applicable sources. This overview was up to date at the time of publication. Please be aware that standards are constantly changing; existing standards are subject to ongoing development, and new standards are always being introduced.[31]

The table below provides an overview of the standards applicable to each component. Not all components are subject to standards; those listed here are explained further on in this section and in Annex 1.

Component	Standard	Comply-or-explain list	Description on page
Testing	• NLQTI		37
Education process support	• E-portfolio NL	Yes	37
Management and use of student information	• LIS		37
Timetabling/calendar	• iCalendar		37
Developing, managing and sharing learning materials	• OAI-PMH	Yes	37
	• NL-LOM	Yes	37
	• Dublin Core		37
	• SCORM		37
	• IMS Common Cartridge		38
	• EPUB3		38
	• HTML5		38
	• CMIS 1.0	Yes	38
	• Edukoppeling	Yes	38
Learning analytics	• Caliper Framework, Sensor API and xAPI		38
Freely available applications	• LTI		23
Data integration	• Open Education API		24
	• Odata		38
Identification	• CIFER		39
Authentication	• SAML		27
Role-Based Access Control	• NIST		39
Group management	• VOOT		30
Authorisation	• OAuth 2.0		30
	• UMA		39

29. For more information on terminology for digital testing, online education and DLWOs, see: *https://www.surf.nl/en/knowledge-base/2013/digital-test-terminology.html, https://www.surf.nl/kennisbank/2015/begrippenkader-online-onderwijs.html, https://www.surf.nl/kennisbank/2014/begrippenkader-dlwo.html.*
30. For more information on the legal framework for cloud services, see: *https://www.surf.nl/kennisbank/2013/juridisch-normenkader-cloud-services-hoger-onderwijs.html*
31. More information on standards: *https://www.edustandaard.nl/standaarden/in-de-praktijk/, http://www.imsglobal.org/, http://adlnet.gov/, https://www.forumstandaardisatie.nl/english/*

3.2 VARIOUS FORMS OF INTEGRATION

Because most applications are not so standardised in practice that they automatically fit together seamlessly, integration infrastructure is required. Infrastructure of this type allows for data to be exchanged between applications and is constructed of multiple components, such as one or more Application Programming Interfaces (APIs) and an Enterprise Service Bus (ESB). Various solutions are available that occasionally overlap with one another.

The components can be classed by various types of integration, with a distinction drawn between:
A. Visual integration
B. Data integration
C. System integration

This model assumes the presence of source systems, such as the student information system (SIS) – the data management application discussed earlier under the 'management and use of student information' component.

A. Visual integration

Visual integration surrounds applications with a graphic shell (the interface) so that users feel as though they are working in a single environment and are unaware that they are using multiple applications. Visual integration makes personalisation easy for users, allowing them to find information and functionalities and to add or remove them to/from the environment as they wish. This involves a mix of user-selected applications and systems from both within and outside the higher education institution. An ideal scenario would allow users to put together their own set of tools. Personalisation is a tangible element for users and one of the key factors determining the user experience. Providing effective personalisation options and allowing users to become the architects of their own learning environment results in powerful tools. Visual integration can be provided via portals, or by mobile applications where a smartphone serves as a personal dashboard and content and functionality can be added or removed via an app store.

Visual integration

Mobile apps
Mobile apps are applications specifically designed for use on a mobile device such as a smartphone or tablet. Mobile apps enrich the functionality of the mobile device and include web apps, native apps and hybrid apps. Native and hybrid apps are installed on the mobile device and are available via an app store. Web apps are accessed via a mobile browser and are comparable to websites. Students and staff want to be able to access information and functionality from underlying systems through a personal environment – in many cases, a personal device. More and more higher education institutions are therefore making components of their digital learning environment available for teachers and students to use on mobile devices.

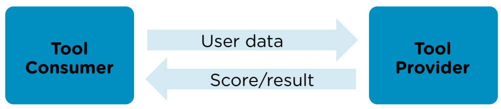
Portals: gateways to the learning environment
A portal allows for a considerable degree of personalisation and visual integration of applications by users. Students use a personalised portal as a general starting point; this forms a visual shell surrounding the underlying systems, which then remain invisible to the user. If the portal supports single sign-on, users only need to log in once to gain access to all of these underlying systems (read more about this in Section 3.3 on identification, authentication and authorisation). The underlying systems are made accessible via widgets, which are small applications that users can add to the user interface of an online environment. They offer limited functionality and combine data from underlying applications. Widgets allow users to design their own portal environment easily by dragging components and services to it or by selecting the types of information they want their personal portal to display. They make this selection using a catalogue of available widgets. Once a widget is no longer being used, it can easily be removed from the personal portal. Various different types of portals exist, such as information portals or collaborative portals.[32]

32. For more information, see the Widgets, Gadgets and Portal Technology report (Widgets, Gadgets en Portaltechnologie): *https://www.surf.nl/kennisbank/2009/rapport-widgets-gadgets-en-portaltechnologie.html*, and the Portals Research Report (Rapport Onderzoek Portalen) by the University of Twente: *http://www.utwente.nl/sb/beleidsterreinen/universitair-informatiemanagement/informatiearchitectuur/inzicht-in-portalen-publiek.pdf*

Avans Collaboration Portal
The iAvans example illustrates how the use of a portal product (Liferay) can produce an integrated collaboration environment (i.e. not specifically a digital learning environment) that integrates functionalities through the use of widgets. The collaborative environment is already in use in the education sector, for example to facilitate collaboration among international students. Access is granted through SURFconext (Avans students/staff) and Onegini (social ID for non-Avans collaboration partners).[33]

LTI

The IMS Learning Tools Interoperability (LTI) standard makes it possible to offer additional services (for example, a WordPress blog or Mediasite lecture recordings) in learning environments such as Blackboard or generic portals. LTI ensures that data can be exchanged between systems, and that username/password combinations are not released to the additional applications by the learning environment. IMS LTI identifies two types of systems: Tool Providers (the systems offering services via LTI) and Tool Consumers (the systems using a service via LTI). Tool Consumers (e.g. a learning management system) send encrypted authentication and other user data to the Tool Provider, such as a digital testing system, which then returns the test score to the Tool Consumer.[34]



Learning Tools Interoperability (LTI)

Technology scouting at the University of Amsterdam using LTI, uPortal and SURFconext Teams for group collaboration
Background: Students and lecturers at the University of Amsterdam (UvA) want increasing control over which tools they use. Even when working in groups, they want the group to be able to choose its own tool to use for collaboration.

So how does it work? The UvA's technology survey used uPortal (also in use for the My UvA student portal) to conduct a study on the flexible selection and connection of groups and group information to relevant tools. Authentication and authorisation ran through SURFconext. The applications used (uPortal, the online forum tool Piazza, and others) support the use of LTI. In this scenario, the LTI consumer is uPortal (developed by the UvA in partnership with Edia and not yet available as a formal uPortal release) and the LTI provider is Piazza.
Users can easily create and manage collaborative groups. Group management is centrally organised and group information can be used in multiple cloud services. uPortal retrieves group information from SURFconext Teams and uses it within uPortal to send data to members of the relevant groups. Here, the details involved are the usernames, email addresses, context and roles (member or manager).
Users log in via SURFconext. The initiating student or lecturer indicates (for example) 'I want to collaborate with the Mathematics 1 group and these are the members' (which can include students at multiple institutions). Next, the initiator selects an LTI application from a list of possible applications that they wish to use for the collaboration in uPortal. The initiator selects Piazza. The link with LTI is then created. The configuration settings are preset, as the LTI component already has a configuration unit in which the data to be exchanged can be specified.
When other students in the group log in to uPortal, they will see the collaborative Mathematics 1 group already available as a tool in Piazza. This process uses 'on-the-fly provisioning': Piazza does not create user accounts until group members log in, as Piazza is not supplied with user information beforehand.

33. For more information on collaboration best practices at Avans University of Applied Sciences portal, see: *https://www.surf.nl/kennisbank/2014/best-practice-samenwerken-binnen-de-portal-van-avans-hogeschool.html*
34. For more information on Learning Tools Interoperability, see: *http://www.imsglobal.org/toolsinteroperability2.cfm*. In 2014, a white paper was published on how the LTI would affect higher education in the Netherlands: *https://www.surf.nl/kennisbank/2014/whitepaper-lti-in-het-nederlandse-hoger-onderwijs.html*

Advantages: Users have control over which tools they use and there are already many applications that support LTI. Previously everything had to be configured beforehand, but on-the-fly provisioning now means setup can be delayed until the initial use. Frank Benneker (UvA): *'SURFconext is a beautiful tool for federated access. SURFconext Teams is effective for forming groups and also works ad hoc, and LTI is a valuable standard. All the pieces are there, so now it's just a matter of finding the right use cases to ensure widespread adoption.'*

B. Data integration

Data integration facilitates communication between various applications. It makes data available using special interfaces, enabling them to be used by other applications in turn.

Data

API

Data integration can make use of APIs, or Application Programming Interfaces, which define access to the functionality or data of an underlying application or system. An API can be used by a third-party client application (such as a website, mobile app or widget) to implement and call up the defined functionality, making the data accessible from multiple applications. A well-known example is Google Maps: the API allows a website to integrate a geographical map sourced from Google Maps.

A single integration infrastructure may use multiple APIs. An application operating as a source system within the integration infrastructure (such as Osiris) can supply an API in order to make data available to an Enterprise Service Bus (ESB) or mobile app. ESBs can also have their own APIs, however. There are APIs that supply data to systems within the same institution (called 'trusted interfaces') and APIs that supply data to external systems (called 'third-party applications').[35]

Open Education API

The Open Education API standard – an initiative of SURFnet and a number of higher education institutions – plays an important part in data integration. It aims to create a standardised REST API for sharing education data such as marks, course credits, schedule information, news and available workstations. Mobile apps are an important driver for the development of the Open Education API standard, however widgets can also be used to access data via the standard. Based on the Open Education API standard, higher education institutions can offer APIs that give third-party applications a standardised way of requesting general and personal data from secured institutional source systems. The Open Education API can be protected using OAuth 2.0, an open secure-access protocol that uses tokens. Each token provides access to specific data from a single website for a certain length of time.[36]

35. For more information, see: *https://wiki.surfnet.nl/display/onderwijsdata/APIs*, and page 9 of the Educause report: *http://net.educause.edu/ir/library/pdf/eli3035.pdf*
36. Open Education API: *www.openonderwijsapi.nl*

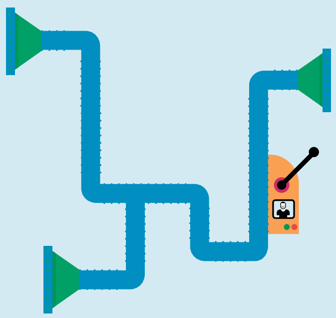
Practical example from Zuyd University of Applied Sciences: Smart data access with Open Education API and single sign-on

With all underlying source systems based on the Open Education API and simplified login using SURFconext's single sign-on, the new intranet at Zuyd University of Applied Sciences is both user-friendly and future-proof.[37]

'The API transmits information from source systems to education applications, such as new applications for checking the current course schedule on your mobile phone or for reserving a workstation while you're still on the train. The basic data come from source systems, but the way they are displayed and their functionality are new. Providing access to the existing source systems through the Open Education API will allow for the development of a host of new applications, without any need to adjust the source

C. System integration

Integration infrastructure brings the separate components of the digital environment together, allowing them to function as a single system. One way of achieving this is to connect all systems to each other individually: the downside to this method is that it requires lots of different connections, which are difficult to standardise and maintain. Another way is to use specialised application integration software such as an Enterprise Service Bus (ESB) or a data warehouse. The advantage here is that only one connection is required per system, to the ESB or to the data warehouse. This method provides a standard way of linking up a variety of different cloud (or other) services. The application integration software connects applications separately so that they can be modified or replaced independently of one another, and converts the data from both the sending (source systems like Osiris) and receiving applications (such as a mobile student schedule app) into a canonical data model (where the apps employ different data models).



Integration infrastructure

Enterprise Service Bus

An Enterprise Service Bus (ESB) simplifies communication between the sending and receiving applications and allows for the exchange, routing, transformation and combination of messages between applications. One of an ESB's tasks is to convert (transform) incoming data from the sending application into the format expected by the receiving application. Adding an ESB component to software architecture can standardise the way applications communicate with each other, as the only requirement is an agreement between the ESB and the receiving applications that use the same service.

It is important to be aware that some integration scenarios do not immediately suggest the use of an ESB, such as when data must be exchanged in the form of files, in bulk, periodically or with external parties. This also bears on identity management, for which more specific solutions are available. Lastly, the use of an ESB is not automatically justified if the applications to be linked already have standard interfaces.[38]

37. Best practice, Zuyd University of Applied Sciences: Smart data access with Open Education API and single sign-on: *https://www.surf.nl/en/knowledge-base/2015/best-practice-zuyd-university-of-applied-sciences-smart-data-access-with-open-education-api-and-single-sign-on.html*
38. For more information on application integration, see: *http://www.wikixl.nl/wiki/hora/index.php/Integratie*

Data warehouse
A data warehouse is a system used to store and combine data. This data originates and is automatically extracted from source systems. The data in a data warehouse cannot be entered or modified by users themselves. Data warehouses include a set of definitions that data must comply with and can respond to both repeat and ad hoc requests from receiving applications relatively quickly without overloading the source systems themselves. This is the difference between a data warehouse and a standard database. Data warehouses have the following characteristics: they are thematically organised, integrated, chronological and frozen.

A 'data vault' is an organisational principle for a data warehouse. Data warehouses include a set of definitions that data must comply with. A database set up according to the data vault principle works the other way around and is premised on the sources. Inholland University of Applied Sciences, for example, employs the data vault principle, which is specially intended to store data from various sources with a range of definitions and levels of reliability. The system is premised on the sources and, in principle, all data are stored, but with a number of additional parameters so that it is always clear where it came from and when it was created.[39]

Canonical data model
Canonical models include definitions of data and concepts and set out rules, procedures and processes. They help to manage complexity and ease communication. Such data models are not application-specific and provide an organisation-wide description of data definitions. Because defining a canonical data model is a lot of work, it is generally advisable to use standards that define models of this type (or parts of them). Some institutions have already begun doing this and are advocates of the joint construction of data models, thereby creating a canonical data model to facilitate cross-institutional data exchange in Dutch higher education.[40]

3.3 IDENTIFICATION, AUTHENTICATION AND AUTHORISATION

The sections above discuss integration infrastructure and the systems that can be used to create it. These systems enable the integration of and interoperability between various components in the digital learning environment so that users perceive all the separate components as a unified whole. The platform must also be accessible and offer options for personalisation though portals and mobile apps that staff and students can add to shape their own digital learning environment. But what about access to protected information and systems? This is regulated by means of identification, authentication and authorisation. Closely related concepts include Identity & Access Management (IAM, based on identities or roles) and single sign-on (SSO, where only one log-in is required to gain access to all components).

Identification: Who are you?
Identification means establishing the identity of a user, such as by having them show their driving licence or passport. The user's identity is then used to create an account in the identity management system.

Identity management system
An identity management system exchanges, matches and synchronises identity data, which are used to grant access to non-anonymous (personal) functionality within applications. All students in higher education are issued with an identity by their institutions, consisting of a unique student number and a password. This identity grants students access to institutional applications and information. Institutions manage these identities themselves, making them the identity provider for staff and students.[41]

39. More information on data vaults: *http://danlinstedt.com/solutions-2/data-vault-basics/*
40. Sources and more information: *http://www.wikixl.nl/wiki/hora/index.php/Integratie*, *http://www.wikixl.nl/wiki/hora/index.php/Bestand:Hoofdstuk7_tabel2.png* en *http://net.educause.edu/ir/library/pdf/eli3035.pdf*
41. Source: *http://www.wikixl.nl/wiki/hora/index.php/Integratie*

Authentication: Are you who you say you are?

The purpose of authentication is to confirm that users are who they say they are. Strictly speaking, however, all that can be proven is that during authentication, a user has used the means of authentication belonging to a particular identity. Authentication concerns accounts and passwords, strong authentication based on knowledge and property, and federated authentication that only requires a person to be recognised and authenticated at a single location.

Federated authentication
National federations provide a generic means of processing authentication and authorisation between institutions (identity providers) and cloud service providers. The federation ensures standardised agreements are in place regarding aspects such as security and privacy, with which all participants in the federation (identity providers and service providers) must comply.

Users log in to all available services using their institutional accounts; they therefore do not need to create a separate account for each service and their passwords are not revealed to the external service providers. This is called ‘federated login’. In principle, this increases accessibility, privacy and security as users only need to remember a single username and password combination. Users grant explicit permission for the exchange of their personal data with external service providers so institutions can comply with the Personal Data Protection Act (Wet bescherming persoonsgegevens).

SAML
Security Assertion Markup Language (SAML) is a standardised language used to exchange information both within and between federations. It is used to perform authentication and for single sign-on. Ideally, applications would no longer require authentication themselves but instead rely on this type of generic authentication functionality.[42]

Strong authentication
Sometimes, it can be desirable to apply more stringent security requirements to applications used for the components of ‘testing’, ‘management and use of student information’ and ‘education process support’, as these applications process data of a more sensitive/confidential nature. Such services require forms of authentication that are stronger than a username and password in order to limit the risk of security incidents.

Somebody who discovers another user’s username and password can easily gain (unauthorised) system access. Remote banking works differently: in addition to a username and password, users require supplementary information to make a payment, such as a physical card and a random reader, a mobile phone or a list of codes. This combination of ‘having something’ and ‘knowing something’ in order to gain access to a data system is known as ‘strong authentication’ and reduces the risk of unauthorised access.

42. For more information on authentication and SAML, see: *https://wiki.surfnet.nl/display/surfconextdev/Authentication+using+SAML* , *https://blog.surfnet.nl/saml-dummies/*

Federated and strong authentication via SURFconext

SURFconext provides federated authentication and single sign-on across multiple cloud applications. It connects education institutions in their role as identity providers with cloud services offered by service providers. SURFconext also includes authentication and authorisation functionality such as single sign-on, cross-institutional and federated login, and strong authentication, and coordinates all privacy and security agreements. Users select their organisation on the WAYF (Where Are You From) login screen, which includes an overview of the identity providers affiliated with the service provider. Users grant explicit permission for their personal data to be shared with external service providers: SURFconext provides this user consent functionality so institutions can comply with the Personal Data Protection Act (Wet bescherming persoonsgegevens).

In this scenario, higher education institutions manage enrolled students' identity data. As higher education becomes more flexible and personalised, there will be an attendant push to put students more in control of their own identity data as needed to access education and other required facilities – for example, to make it easier to take courses at multiple higher education institutions without requiring multiple enrolments.
In the years ahead, SURFconext will investigate new forms of authentication to support this type of student 'mobility'. Text messages, tiqr (a smartphone app) and Yubikey (a USB key) are used for strong authentication to access cloud services. Users log in using their institutional account and are then prompted to confirm their identity using an additional means of authentication.[43]

Social ID

For people who are affiliated with an institution but whose identity data are not managed by that institution, the use of a social networking account (such as Facebook or LinkedIn), known as a 'social ID', may be appropriate. In a digital learning environment, 'guest' access is relevant to components such as 'collaboration' and internships and final projects'.

In general, the use of social networking accounts must be treated with some caution because their validation process is usually less advanced, giving the identity a low level of trust. It is therefore wise to restrict access for such accounts to personalised selections of information with a low level of confidentiality, such as viewing schedule information (often publicly available).[44]

Guest access via SURFconext

Users who do not work or study at a SURFconext institution can still to log in to SURFconext cloud services. These 'guest' users can log in using a social networking account (such as Facebook, Twitter, LinkedIn or Google). Onegini is used for this purpose, which is a special application that provides guest access to third-party applications. Avans University of Applied Sciences uses Onegini to enable cross-institutional collaboration within the iAvans collaborative portal, for instance for projects involving external parties and educational activities with international students.[45]

43. For more information on SURFconext and Strong Authentication, see: *https://www.surf.nl/en/services-and-products/surfconext/what-is-surfconext/surfconexts-strong-authentication/index.html*
44. Source: *http://www.wikixl.nl/wiki/hora/index.php/Integratie*
45. For more information on best practices at Avans University of Applied Sciences, see: Cross-border education with guest access via Onegini: *https://www.surf.nl/en/knowledge-base/2015/best-practice-avans-university-of-applied-sciences-cross-border-education-with-guest-access-via-onegini.html*

Authorisation: What are you allowed to see?

Authorisation is the allocation of permissions; certain information is used to determine which services a user is allowed to access, for example. Additional identity information is required for this purpose, which can be obtained based on the role of a user within a project or organisation. Publishers, for example, can make certain publications available to specific staff members at an education institution. Authorisations may also be allocated based on a group to which a student or staff member belongs, such as a student taking Statistics, who belongs to the group of all students taking this course. In these scenarios, people are granted access to an application. People may also authorise an application to access personal data from other applications (machine-to-machine access).

Role-based access

Another way of granting user groups access to certain information and applications is 'role-based' access, a method that allows the configuration of access controls for information systems. Associating a user's organisational role with a role in an information system makes it easy to set the user's rights. For example: students have access to service X. If John is a student, then service X will be visible to him. The various roles must be configured and managed, usually using an identity management system. Experience has taught us that implementing a completely role-based identity management system in higher education institutions is difficult, given the wide range of roles and the autonomy of faculties. In practice, only basic roles are defined, such as students, staff and guests. This system, combined with information on a person's faculty/department and organisational unit, seems to be sufficiently robust for practical authorisation purposes.[45]

Role-based access via SURFconext

One way of allocating user roles for a cloud service is through attributes. As soon as a user logs in, SURFconext sends additional information about the user's identity and role(s) to the service provider. These additional pieces of information are called 'attributes'. The 'affiliation' attribute, for example, can be used to identify a user's role within the institution. This is particularly useful for making authorisation decisions within connected services as some applications allocate different rights to staff members than to students, or may only grant access to staff, for example. The affiliation attribute may contain several values that cannot be freely determined; SURFconext supports only the following values:

- student
- employee (including support staff)
- staff (academic staff – employees directly involved in the institution's primary process)[47]

Group management

The 'organisation of learning' component described in Section 2 is meant to grant students easy, clear access to the correct content and applications required for learning. These include functionalities such as assigning students to groups, assigning students (or groups of students) to courses and providing access management. The success of this component in the digital learning environment depends entirely on effective group management. Collaboration in a variety of groups requires a clear overview of which groups users belong to. A user may belong to multiple groups simultaneously. Neither is the system static, as users often are only members of a group temporarily, nor are they always homogeneous. Characteristics of group members may also differ, such as a group of first-year students with a third-year mentor. Solutions to these types of problems are rarely straightforward. Currently, group management is still a major challenge to many institutions.

46. For more information, see: *http://www.wikixl.nl/wiki/hora/index.php/Integratie*
47. For more information on SURFconext's use of attributes, see: *https://wiki.surfnet.nl/display/surfconextdev/Attributes+in+SURFconext#AttributesinSURFconext-Attributeoverview*

The organisation of learning is a core element of a learning management system (LMS), of which group management forms a part. This group information can be used by the LMS itself, or made available via an API and re-used by other applications (using the Open Education API standard, for example). SURFconext also provides a functionality to enable the use of group information in multiple applications: central group management.

Group management via SURFconext

Central group management
SURFconext Teams can be deployed as a tool for central group management. With SURFconext Teams, users can easily set up an online group with members from different institutions. The group can potentially be used for SURFconext cloud services: it only needs to be created once, after which it is ready for use by various cloud services. Group membership grants team members access to various applications, as well as authorisations (for a practical example at iAvans, see box on page 30).[48] A SURFconext Team can consist of both individual members and groups external to the institution. In this way, SURFteams enables the creation of any combination of groups or collaborative arrangements.

Institution as group provider
External group providers can also be linked to SURFconext. If an organisation wishes to re-use groups in SURFconext that are defined and managed by the institution itself, the organisation is known as an 'external group provider'. In addition to links for individual users, a link for groups must also be created using the SURFconext VOOT protocol. VOOT stands for 'Virtual Organisation Orthogonal Technology', and the protocol allows external group providers to be linked to SURFconext and for the sharing of group information, for instance about the groups to which a single member belongs or the members of a particular group. An external group provider is supplied by a higher education institution, which defines and manages its own groups. After the links have been created, SURFconext can re-use the group information within linked cloud applications. SURFconext currently supports VOOT version 1.0.[49]

International collaboration
A new pilot service is available for international teams: eduTEAMs. Many collaborations extend beyond the Netherlands. eduGAIN offers a federated authentication solution for international collaboration. eduGain is a partnership between the education and research federations in virtually all European countries (and several outside Europe). eduTEAMs has been linked to eduGAIN, giving all eduGAIN Identity Provider users the ability to create and manage teams. For example: the functionality enables a Dutch institution's Wiki page to grant an entire team instant access to a particular 'space', and the SharePoint environment of a Spanish university to offer a 'team site' to the same team.[50]

OAuth 2.0 (Open Authorization)
OAuth 2.0 is an open authorisation standard to which major cloud service providers and other parties (such as Microsoft, Google and Amazon) have committed themselves. OAuth2.0 ensures that only authorised apps can access end-user data that a given end-user has authorised the app to access. One example of a situation in which OAuth 2.0 offers a solution is a mobile app that retrieves a student's personal schedule information from the university system without granting the app access to the student's email, exam results or course registrations.

48. iAvans: A practical example *https://www.surf.nl/kennisbank/2014/best-practice-samenwerken-binnen-de-portal-van-avans-hogeschool.html*
49. For more information on VOOT, see: http://openvoot.org/ en https://wiki.surfnet.nl/display/surfconextdev/Group+Provider+koppelen+aan+SURFconext.
50. More information on eduTEAMs: group management for international collaboration:
https://blog.surf.nl/en/eduteams-group-management-for-international-collaborative-projects/

In such complex situations that involve granting users access to their own data using either their own or third-party applications, access management is fairly tricky due to the involvement of multiple parties – users, data providers and the application used. Users should actually be able to grant an application (a website, a mobile app, etc.) secure access to source systems on their own behalf.

OAuth 2.0 uses tokens, eliminating the need to issue confidential details such as a username or password. Each token only provides access to specific data from a single application for a certain length of time. A given programme can be configured to have access to the data for only one year, for example, after which access can be renewed if necessary.[51]

51. More information on OAuth: *https://blog.surf.nl/en/oauth-beginners/*

CASE STUDY: UTRECHT UNIVERSITY

PROOF-OF-CONCEPT FOR THE NEXT-GENERATION PERSONAL LEARNING ENVIRONMENT

In addition to surveying user needs and wishes for the e-learning environment of the future, Utrecht University (UU) is also exploring the technological possibilities under the auspices of the Educate-it[52] programme, which supplies information and technologies to advance innovation in education. To determine what does and does not work, the UU's Faculty of Science asked a group of students to develop a proof-of-concept for the next-generation learning environment. The result is called PROFE, it forms part of a portal that connects flexible storage services, making it a kind of 'middleware' for storage.

Traffic control

The students started from the assumption that a learning environment consists of diverse components – systems and services – that together form an integrated whole. The learning environment acts as a kind of 'traffic controller': instead of storing copies of files from source systems in the learning environment, the environment displays the requested information from the source systems to users in a user-friendly manner. Users only need to log in once to gain full access (single sign-on). As the foundation for the learning environment, the students decided to use Laravel, an open-source PHP framework based on a commonly used programming language. The advantage of a framework like Laravel is that it provides structure, can be adopted by other developers and treats appearance and functionality as two separate elements. Furthermore, the framework already provides the basis for functionalities such as security, authentication and sign-on, reducing the amount of low-level development required.

Initial functionality: document storage

Document storage and sharing was the first aspect tackled by the students. The UU's requirement was that these processes should be independent of the service used by students and lecturers, whether it be SURFdrive, Google Drive or Dropbox. For example, a student should be able to write an assignment in Google Drive and submit it to the lecturer's SURFdrive, where they can access it directly for marking. To achieve this, students built a FileStorage Facade that is compatible with all services. The FileStorage Facade deals with all the differences between the services (SURFdrive, Google Drive, Dropbox) so that users always see the same thing.

Portal

The learning environment portal shows users what kinds of information are available, such as course pages and a timeline. New content modules can be added easily. The timeline is another important component of both the learning environment and the portal: when lecturers apply changes to the calendar, for example, students can click straight through to the course module containing the lecture files. In principle, any service can supply data to the timeline.

Effective documentation, libraries and standards

Effective documentation on, for example, how APIs work, as well as libraries with standard codes are very important when linking services and applications. According to the students, Google and Dropbox manage this very well. Of course, the more the services resemble one another, the easier they are to connect. If all services use OAuth, for example (see page 30), linking them together is much easier. The students have noticed that standardisation is becoming more and more common (REST API is an example), making the linking process easier, provided of course that services actually keep to the standards and do not introduce any changes. In practice, this does not always prove to be the case – not even with standards like Learning Tools Interoperability (LTI) – meaning some repair work is required.

Many services not ready

One important discovery made by the students was that many services are not yet ready for inclusion in an integrated learning environment. Often there is no API available (Osiris being one example), which means no data can be obtained without accessing the source files directly. Nor could the students find a scheduling or testing system with both a good API and a licence. *'Although we do expect things to progress more quickly if institutions collectively demand good-quality APIs with documentation.'* They also noticed that many suppliers are continuing to expand on their services, creating mini-learning environments and making the inclusion of components from other packages virtually impossible.

52. More information on Educate-it: *http://educate-it.sites.uu.nl/en/uu.nl/*

'As long as many services remain unsuitable for inclusion, building a fully integrated learning environment will remain impossible', say the students. *'Ideal services are those that are very good at one thing, not average at a whole lot of things. Google lets you use Docs, for example, without having anything to do with their other services.'*

Linking services is a huge job

The process of linking services should not be underestimated, the students concluded. ICT developers do not need to know everything about a service, but they do need to know its capabilities in abstract terms, such as *'I now want to assign this student a mark'. They believe it will take quite some work to evaluate what each service can do and how the functionality can be made available in a uniform manner. 'It means a separate project for each service. It would be nice if institutions were to share their knowledge and experiences of linking services.'*

4. CHALLENGES FACING THE DIGITAL LEARNING ENVIRONMENT OF THE FUTURE

Creating a future-proof, flexible and personal learning environment is a challenging task for higher education institutions. This document provides some openings for designing such systems, based on components, applications and integration possibilities. Below we provide a brief summary of the key challenges facing higher education institutions and suppliers.

1. Are the basic systems in order?
An important prerequisite for the development of an integrated learning environment is that basic systems such as the Student Information System (SIS) are well organised. Only then can data and systems be integrated. The organisation of role-based access control is a major challenge for higher education institutions, for example, because information on roles is often spread out across various systems and because users usually adopt different roles for different areas of responsibility.

2. Is there a fundamental architectural concept?
Application functionalities and options often overlap, which is why it is important to work according to an overall architectural concept. What does each application do and how can functionality be re-used to create added value? One point to keep in mind is how applications are integrated (including those chosen by students and lecturers). Sometimes use agreements will suffice, such as on uploading the results of one application into another. Another architectural principle involves separating data and processes.[53]

3. Is it clear which application provides which functionality?
Applications should preferably have a modular structure, and APIs should make it easy to filter out a single functionality from the source system. This is often not possible in practice. An even better approach is for applications to specialise and excel at a single aspect of functionality. Many applications are continually being expanded with new functionality, making it more difficult to integrate components. For this reason, some institutions interviewed during the preparation of this document advocate a series of applications, each concentrating on a single functionality.

4. Are there standards in use?
Standards and APIs are very important for the integration of individual components. Application suppliers must therefore make an effort to adopt the most relevant standards and to offer APIs paired with good documentation. This will furnish developers with components that they can then fit together. Institutions can help by imposing requirements on the suppliers and applications they decide to use.

5. Is any thought being put into management and control of the learning environment?
Institutions need to consider the governance of their digital learning environment. Who will supply what information and who will need to access it? Who decides on what? Who is allowed to use the applications and how will this affect students' and lecturers' freedom of choice?

53. Further information: *https://www.surf.nl/binaries/content/assets/surf/nl/kennisbank/2014/visie-op-de-digitale-leer-en-en-werkomgeving-werkboek-met-adviezen-opdrachten-en-voorbeelden.pdf*

6. Is the institution ready for a digital learning environment?

The culture at higher education institutions will sometimes also constitute a hurdle. Institutions have to take leadership on standardisation and on the collaboration needed to enable exchange and integration. In working towards the actual creation of next-generation digital learning environments, it is worth keeping the following advice from the Educause report (April 2015) in mind: ‘The culture of higher education teaching and learning must evolve to encourage and even demand the realization of the Next-Generation Digital Learning Environment (NGDLE). We need to adopt “NGDLE thinking,” whereby the functional domain set (page 8) feels to us like a natural fit for any learning environment.’

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IN CONCLUSION

There is still a ways to go both in creating a more flexible and personal digital learning environment and in developing a vision for the next-generation digital learning environment. This is a challenge that Dutch higher education institutions can tackle together, and for which SURF offers its support.

This document is based on an analysis of the literature and current institutional practices, and an extensive survey of products on the market and services such as SURFconext and the Open Education API developed by SURF over recent years. This approach has made it possible to address both the technical and functional aspects of flexible and personal learning environments. This document also contains many references to supporting documentation with more in-depth information. As such, it offers an up-to-date overview of the current state of play in the design of flexible and personal learning environments and a basis for further discussion, synchronisation and collaboration among institutions and suppliers.

ANNEX 1
STANDARDS FOR THE DIGITAL LEARNING ENVIRONMENT

The table in Section 3 presents the standards that are relevant to digital learning environments. The standards not explained in Section 3 are detailed below.

NLQTI
NLQTI is the Dutch profile for the international IMS-QTI standard. QTI stands for 'Question and Test Interoperability' and is what enables test items and tests to be shared between different testing systems and learning environments.[54]

E-portfolio NL
The E-portfolio standard allows individual competencies to be monitored. The advantage of this standard is that students and learning professionals can take their portfolio with them to different organisations.[55]

LIS
The effective exchange of digital pupil data and learning data requires agreements on exactly which information is to be exchanged and how. One of the international standards used for this purpose is LIS, or Learning Information Services. LIS is an extremely comprehensive and complex standard for the exchange of pupil data, group data, course data and learning outcomes. It describes both the data (the data model) and the transfer method. LIS plays a key part in linking systems such as student information systems and learning management systems. The OneRoster standard is a subset of the LIS standard focusing on schedule information and marks.[56]

iCalendar
iCalendar is a format for the exchange of schedule and calendar information such as meeting requests and tasks. Support software such as an email program or a digital calendar is always needed to use the data.[57]

OAI-PMH
OAI-PMH stands for Open Archives Initiative Protocol for Metadata Harvesting and is a standard for the harvesting of metadata (based on the Dublin Core metadata standard) from repositories. 'Metadata' refers to the properties of and additional information about documents or other objects, such as author details, title, publisher, language, etc. A repository is a digital storehouse where digital sources can be saved in a form accessible online. OAI-PMH facilitates the collection of this metadata (not the documents themselves) from various repositories, enabling them to be searched for documents and objects from one central system.[58]

NL-LOM
Making learning materials searchable requires a clear, unambiguous description of the materials using metadata regarding the type of information, file formats, authors, target groups, etc. Teachers can then use this metadata to find an appropriate learning arrangement. NL Learning Object Metadata (NL-LOM, a Dutch profile for the international IEEE LOM standard) is used for describing metadata and assigning it to educational content to enhance its searchability and comparability.[59]

Dublin Core
Dublin Core is an international ISO standard used to describe metadata for learning materials. In addition to the simple description using 15 metadata fields, the standard can also be employed to combine various metadata standards, thereby promoting interoperability.[60]

SCORM
Data playback and exchange is important for the effective use of digital learning resources. SCORM (Shareable Content Object Reference Model) is a collection of agreements focusing on this functionality. SCORM originally assumed that online learning (pre-programmed in a special playback environment for learning materials) would take place via a web browser. Now, however, online learning takes place on all kinds of different mobile and other devices that are interconnected via the Internet. SCORM 1.2 and SCORM 2004 respond to these developments; both versions consist of a 'runtime environment' and 'content aggregation model' component, to which SCORM 2004 has added a sequencing and navigation specification. The runtime environment describes how content will behave if it is used within the learning management

54. More information about QTI: *http://www.imsglobal.org/question/*
55. More information on E-portfolio: *https://www.nen.nl/NEN-Shop/Vakgebieden/ICT/ICTnieuwsberichten/Publicatie-NEN-2035-Eportfolio-NL.htm*
56. More information about LIS: *http://www.imsglobal.org/lis/*
57. More information on iCalendar: *http://www.calconnect.org/CD1012_Intro_Calendaring.shtml*
58. More information about OAI-PMH: *https://www.openarchives.org/pmh/*
59. More information about NL-LOM: *https://www.edustandaard.nl/standaarden/afspraken/afspraak/nl-lom/1.01/*
60. More information on Dublin Core: *http://dublincore.org/documents/dces/*

system and the content aggregation model describes how the content should be imported into the learning management system as an XML file. The sequencing and navigation specification can be used to determine how users navigate through the content.[61]

IMS Common Cartridge

IMS Common Cartridge is a collection of open standards for the description, organisation and exchange of teaching materials between learning materials and systems. Learning materials are published in a standard format so they can be used in a learning management system that supports it. IMS Common Cartridge also provides a new model for publishing online materials according to a distributed, modular and flexible method.[62]

EPUB3

The EPUB3 standard is the successor of EPUB2 (still frequently used), and is a standard for publishing content (electronic publication). EPUB was designed to for reflowable content, allowing a book text to adapts to an e-reader screen and the desired font and font size. EPUB files are what are known as ‘containers’, or collections in the form of .zip archive files containing XML, HTML, SVG or CSS files. The EPUB 3 standard mainly focuses on multimedia and interactivity, for example making it possible for videos to be integrated (embedded) into publications. Not all e-readers support the standard yet, however. In 2014, IMS (the administrator of LTI, QTI and other standards), IDPF (the administrator of EPUB) and other parties partnered to combine native web content formats (such as EPUB3) and education technology integration standards to form EDUPUB, the ‘next generation of educational content interoperability’.[63]

HTML5

HyperText Markup Language 5 (HTML5) is the newest completed version of the HTML standard. It is a markup language used for the specification of content, intended primarily for the World Wide Web. HTML5 has been a standard of the World Wide Web Consortium (W3C) since October 2014. Although the standard is complete, support for specific functionalities in certain browsers is still a concern. There are a number of changes relative to HTML4.
HTML5 enables offline availability of web applications: when visiting an application for the first time, the user automatically downloads the files required by the web app, after which the application can be used offline. If the user makes changes to an offline application, the changes are sent to the server the next time the computer connects to the Internet. The option to implement drag-and-drop functionality has been added and tags are available that allow interactive content to be played back without the use of a Flash Player plugin.[64]

CMIS v1.0

The CMIS v1.0 standard makes unstructured data in content management system (CMSs) and document management system (DMSs) content repositories accessible so that these data can be exchanged with other CMSs and document management systems.[65]

Edukoppeling

Edukoppeling is the education-specific version of the Dutch government-wide Digikoppeling standard. Edukoppeling describes the transaction standard for electronic data exchange in education. It outlines the ‘behind the scenes’ exchange of data between two organisations and is intended to facilitate the predictable and secure transfer of confidential data between two parties (pupil and student personal data, for example).[66]

Caliper Framework & sensor API, and xAPI (formerly TinCan)

Collecting accurate learning analytics data requires various sources to be connected to a Learning Record Store. This can involve all manner of systems, including the digital learning and working systems described in the HORA (such as the LMS and SIS described above), but also web content management systems, video management systems, learning content systems, etc. that users use.
Given the wide variety of systems involved, it makes sense for these systems to communicate with the Learning Records Warehouse using a single protocol. There are two options for this: xAPI, and the Caliper Framework & Sensor API, both of which make it possible to describe and communicate user ‘activity’. These two standards share many similarities and, in theory, it should be possible to store data from the Caliper Sensor API in an xAPI warehouse.[67]

Odata

Open Data Protocol (Odata) is an open protocol for the development and integration of REST APIs and is used to make data from databases, content management systems and websites available to third-party applications. REST is an architecture standard that separates clients and servers. This improves scalability, as systems are constructed from separate elements that communicate with each other via HTTP and JSON.[68]

61. More information about SCORM: *http://scorm.com/*
62. More information about IMS Common Cartridge: *https://www.imsglobal.org/cc/ccv1p2/imscc_profilev1p2-Overview.html*
63. More information about EPUB: *http://idpf.org/epub*
64. More information on HTML5: *http://www.w3.org/TR/html5/*
65. More information about OASIS: *https://www.oasis-open.org*
66. More information on Edukoppeling: *http://www.edustandaard.nl/standaarden/afspraken/afspraak/edukoppeling/1.1/*
67. For more information on TinCan and Caliper, see: *http://tincanapi.com* and *http://imsglobal.org/caliper/*
68. More information on Odata: *http://www.odata.org/*

CIFER

CIFER stands for Community Identity Framework for Education and Research and is an initiative aimed at developing an extensive, community-based approach to identity and access management (IAM). The aim of the CIFER API project is to create APIs for IAM in research and education.[69]

NIST / INCITS 359-2004

The key feature of Role-Based Access Control (RBAC) is that individuals are allocated rights according to group membership, based on their role within an organisation or operational process. The NIST RBAC model is a standard for role-based access control.
It was developed by the NIST (National Institute of Standards and Technology) and is now being managed by the International Committee for Information Technology Standards (INCITS). The most recent version is INCITS 359-2012. The standard consists of two parts: a reference model and the functional specification of the model's components. The reference model is a collection of four components: the Core RBAC, the hierarchical RBAC, a Static Separation of Duty Relations and a Dynamic Separation of Duty Relations. These components provide a standard with a vocabulary of terms. For example, the Core RBAC component defines a minimum collection of RBAC elements, sets of elements and relationships that are needed to create a role-based access control system.[70]

UMA

User-Managed Access (UMA) is an OAuth-based protocol developed to provide users with a single clear location where they can determine who (or what) has access to their online personal data (such as identity attributes), content (such as photographs) and services (status updates).[71] It is expected that students will increasingly access ICT services from service providers directly, instead of through their own institution's ICT service. A central identity will allow graduates to extend contracts they concluded as students (possibly subject to different supplier conditions).
Thanks to SURFconext, institutions issuing identities (identity providers) already need only connect to SURFconext instead of to every single individual service provider. A major benefit of this system is that students do not need to use their password with the service providers. Should SURFnet and the institutions decide to introduce a central identity, this would mean SURFconext would expand its architecture and take over more institutional tasks.
One key difference is that the authentication process will then also be moved to SURFconext and will no longer be carried out by institutions, as is currently the case. Of course, there are also drawbacks and risks to a central architecture. Over the year ahead, SURFnet will investigate whether there is enough support among institutions, possible approaches and their costs and legal consequences.

69. More information on CIFER: *https://spaces.internet2.edu/display/cifer/CIFER+Home*
70. More information on RBAC: *http://csrc.nist.gov/groups/SNS/rbac/*
71. More information on UMA: *http://kantarainitiative.org/confluence/display/uma/UMA+FAQ*

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