How to create a digital learning environment consisting of various components and acting as a whole?

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1. ABSTRACT

Many institutions strive to provide education that matches the learning needs of each individual student. This places high demands on the digital learning environment (DLE) of an institution. One system that meets all the needs and requirements of every student and lecturer, does not exist, which is why a modular approach seems the obvious choice.
In 2016, SURFnet translated this modular approach into a functional model for the DLE. This resulted in thirteen components for the DLE, that support several educational processes. Splitting the DLE into components is supportive for institutions in two ways: 1. It helps institutions to decide to what degree of control and management the components have to be placed in the architecture of the digital learning environment; 2. It helps institutions to determine in which way the components are connected and able to interact.
These connections and interactions are defined in a functional model. In this functional model, the following standards are essential: IMS LTI for Interoperability and Integration, IMS LIS for Personalization, xAPI for Analytics, Advising, and Learning Assessment, SAML/VOOT for Collaboration and OOAPI for Accessibility and Universal Design.
By doing this, SURFnet created a frame of reference for institutions, that helps them with the development of their own digital learning environment. To gain hands-on experience with a modular learning environment, we developed a “demo-DLE”, based on the functional model, which demonstrates the possibilities of a modular DLE for education.

2. INTRODUCTION

Many institutions for higher education aspire to make education more personal and more flexible. They also strive to provide education that matches the learning needs of each individual student. This places high demands on the digital learning environment (DLE) of an institution.
One system that meets all the needs and requirements of every student and lecturer, does not exist, which is why a modular approach seems the obvious choice.

Educause (2015) suggests a “Lego” approach to realizing the digital learning environment, where the DLE consists of several interchangeable and expandable components. These components give individuals and institutions the opportunity to construct learning environments tailored to their requirements and goals.

In 2016, SURFnet translated this vision into a functional model for the DLE. Together with technical architects of several institutions, we defined thirteen components, that support several educational processes. Then, we defined the interoperability between them and placed the components in a functional model. By doing this, SURFnet created a frame of reference for institutions, that helps them with the development of their own digital learning environment. To gain hands-on experience with a modular learning environment, we developed a “demo-DLE”, based on the functional model, which demonstrates the possibilities of a modular DLE for education.

SURFnet is the Dutch National Research and Education Network (NREN) representing all Dutch institutes for higher education and research. SURFnet's mission is to boost the quality of education and research through the support, innovation, development and operation of an advanced, reliable and interconnected ICT infrastructure, enabling the potential of ICT to be harnessed to its full extent. One of the innovation topics which SURFnet addresses, is the Digital Learning Environment. This is done in a multi-year innovation program in which all institutions for higher education can participate.

In this paper we present the components of which a DLE can consist, we present the way the components can interact with each other in a functional modal. We will conclude with the setup of the "demo-DLE".

3. COMPONENTS OF A DIGITAL LEARNING ENVIRONMENT

The modular digital learning environment will consist of a variety of (often pre-existing) components that students and teachers canuse as needed. Some components will be available to all students and teachers at an institution, and others need autorization. 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.

We use 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 is familiar to the education sector, following the 'education application model', which is one of the reference models in the Higher Education Reference Architecture (HORA). This 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 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.

A component is not the same as an application. Some applications can be used for several components at the same time, such as the Learning Management System (LMS). An LMS combines components such as communication, collaboration and submission and assessment of assignments. However, some applications cover a single part of a component. One example is plagiarism checking, which falls under 'Submission and assessment of assignments'.

In this section describe the significance of each component and exactly what it entails.

3.1. Organisation of learning

The 'organisation of learning' component (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. The organisation of learning is a key aspect of learning management systems.

3.2. Testing

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. Crucially, the digital learning environment will have to support various testing methods.

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.

3.3. 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.

3.4. 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.

3.5. 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 personalized learning pathways. Responding effectively to these changes represents a challenge to institutions.

3.6. 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.

3.7. 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.

3.8. 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 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.

3.9. 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.

3.10. 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.

3.11. 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.

3.12. Multimedia

Video and other multimedia applications like Virtual Reality, 3D-printing and so on, are playing an increasingly important role in education. 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 management and playback functionality for several multimedia resources.

3.13. Freely available applications

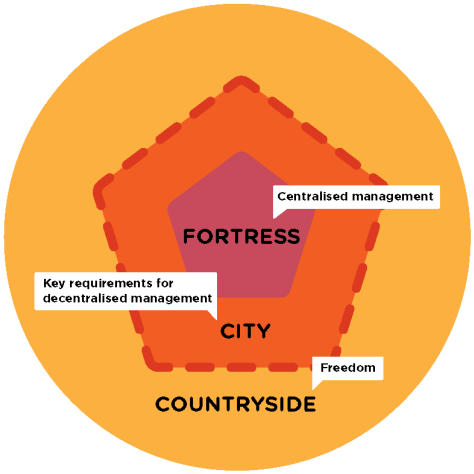
In addition to the applications and systems provided by institutions, students and teachers also use social media, software and apps in their learning process, including apps they create themselves. Institutions can take advantage of this by facilitating the ongoing addition of new tools to their digital 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.

4. THE USEFULLNES OF HAVING COMPONENTS DEFINED

Splitting the DLE into components is supportive for institutions in two ways:

1) It helps institutions to decide to what degree of control and management the components have to be placed in the architecture of the digital learning environment;
2) It helps institutions to determine in which way the components are connected and able to interact.

Both the decision on the degree of control and management and the determination of the interoperability of the components are described in the following paragraphs.



4.1. The metaphor of the fortress and the open city.

Regarding to the considerations of the DLE of an institution, SURFnet developed the metaphor of the fortress and the open city. It compares the learning environment to the medieval formation of a city surrounding a fortress. This metaphor demonstrates that the degree of control and management of the different components varies within the institution.

The FORTRESS itself covers everything that is subject to centralised management (across the institution), and for which the institution is accountable. This includes functions where strategic information is processed as well as formal information for which the institution is held accountable by third parties.

Figure 1: The metaphor of the fortress and the open city

This information is documented in the core components. The fortress is characterised by limited freedom and an aim for standardisation. This standardisation enables a flexible approach to the digital learning environment.

In the CITY, research, studying, learning and working take place with the help of information from the fortress. There is more freedom in the city, and management is often decentralised (taking place within services, faculties, degree programmes and teams). However, the institution still sets criteria that must be met.
In the COUNTRYSIDE surrounding the fortress and the city, it is users themselves who decide what they do, with no interference from the institution.

In 2016, SURFnet has given each component a score on the desired Confidentiality, Integrity and Availability of the data within the component. Components with a high score in one (or more) of the three areas are placed in the fortress. These are the components over which the institution requires the greatest degree of control. The components that are placed in the city have a medium or low classification, and stand in direct relation to the execution of education. They also handle known data over which a certain amount of control is required. Typical countryside components are those with a medium or low classification that involve unknown data.

Table 1: CIA classification of the components

	Confidentiality	Integrity	Availability	Most important business object/ piece of data
FORTRESS				
Organisation of learning	Low	High	Medium	Learning activity
Testing	High	High	High	Test material
Submission and assessment of assignments	Medium	High	Low	Test result
Management and use of student information	High	High	Medium	Participant
Timetabling	Low	Medium	High	Timetable
Learning analytics	High	Medium	Medium	Learning activity report[8]
CITY				
Developing, managing and sharing learning materials	Low	Medium	Medium	Learning materials
Education process support	Low	Medium	Medium	Progress
Internships and final projects	Low	Medium	Medium	Internship/final project activity[9]
COUNTRYSIDE				
Communication	Low	Medium	Medium	-
Collaboration	Low	Medium	Medium	-
Multimedia	Low	Medium	Medium	-
Freely available application	Low	Medium	Medium	-

The classification shows how the components can be positioned within the IT landscape of the institution. Next, the interoperability of the components can be defined. This will be described in the following paragraph.

4.2. Connection and interaction between components

Components consist of a number of functionalities, and these communicate with eacht other, even across components. In order to structure and streamline this communication, it is a good idea to use standards. SURFnet (2016) defined for each component, which data can flow in and out and what standards apply to this exchange of data. This resulted in the creation of an exemplary implementation model that can be used when establishing a digital learning environment.

For each component we described where it stands in relation to other components. We indicated which data the component generates and uses, whether is is in- or outgoing data and what standards can be applied for this purpose.

The figure below shows an example of the 'Testing' component.

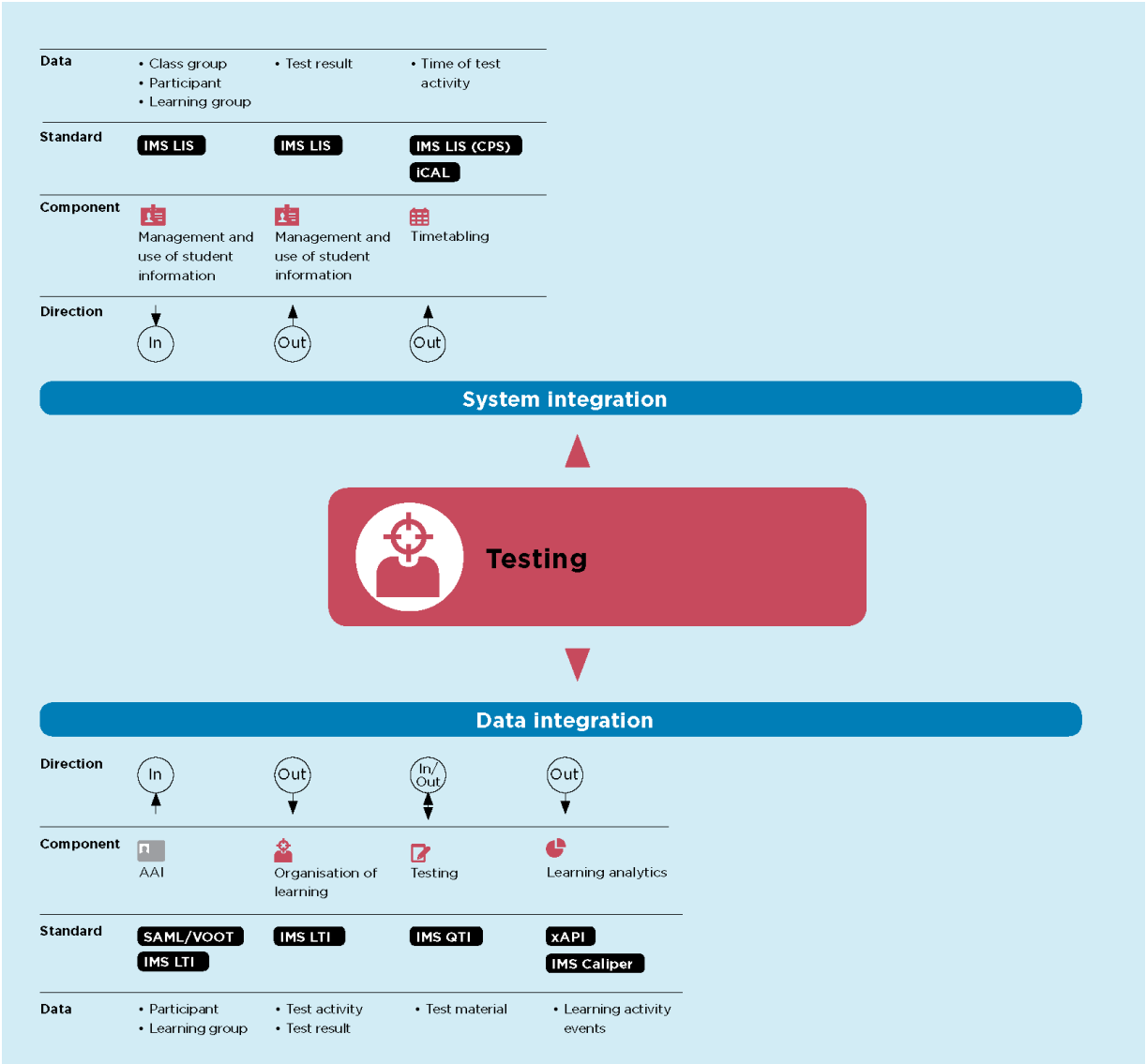


Figure 2: Overview of standards and data flow of the 'Testing' component

The description of each component brings to light the mutual dependency of the components. A component requires certain data from other components in order to function properly. This means that a component has ownership of particular data. This component must then be able to supply this data.

In the example of the Testing component, it is shown that it relies on participant and group data from the 'Management and use of student information' component, which is supplies using IMS LIS on the System Integration level. The Testing component provides in return the test result data to this component.

This underlines the mutual responsibility of components for one another. This interlinkage between te components can be illustrated in two ways:

First, figure 3 'system integration', depicts the interconnections between the core components with the first most relevant standard. The data that usually is exchanged regards student, group and course data as well as test results and unit of study results. This type of integration mostly takes place in the confinement of the fortress, and is based on the IMS LIS/OneRoster specification. Access to this type of data from outside the fortress is achieved through the authentication and authorization infrastructure (AAI) and other means of integration.

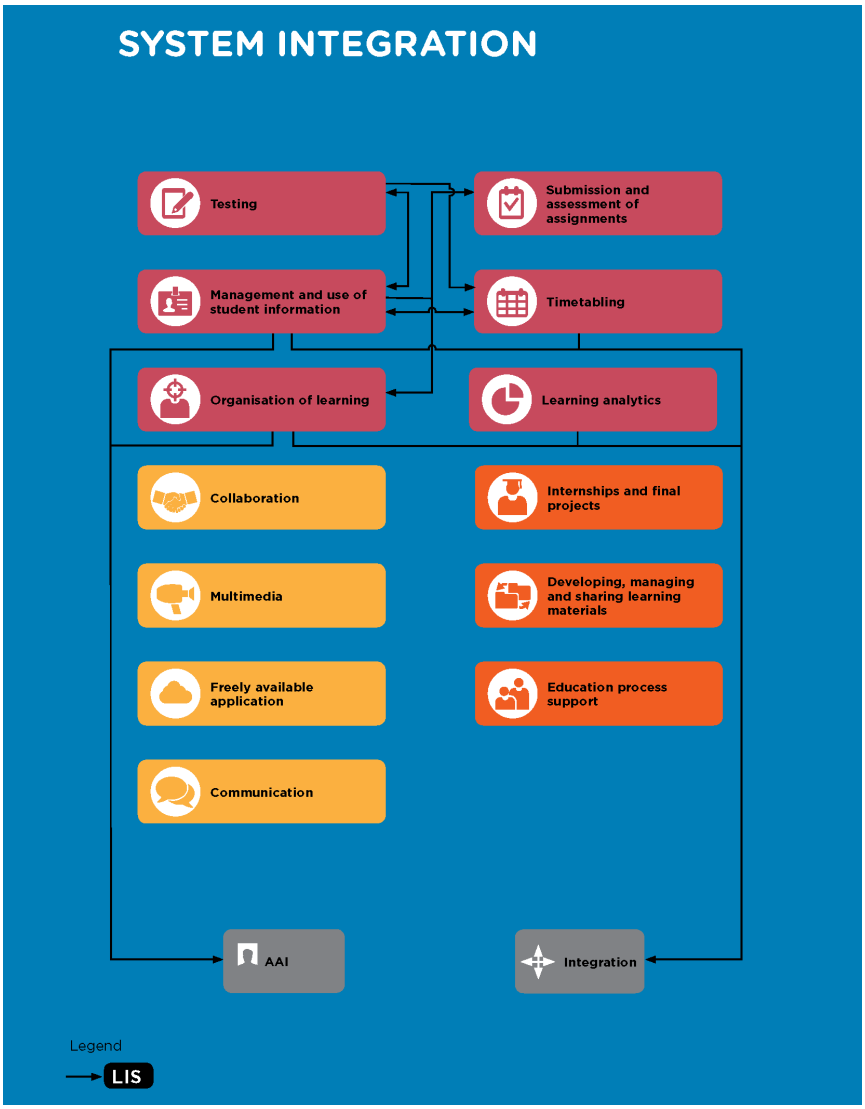


Figure 3: System integration

Second, the figure ‘data integration’ depicts the other most relevant standards for data exchange between the different components. Information handeled by the fortress components is provisioned to other components in the city and country side by means of integration with the Open Educational Apllication Programming Interface (OOAPI). The further shaping of organisation of learning is realized through IMS Learning Tools Interoperability (LTI).
This specification enables components to start and provides them with relevant data, such as personal data and group data. Furthermore LTI offers the possibility of responding with student results achieved in a component to the component that initiated it, for example ‘organisation of learning’. The aggregation of all students’ learning activity events generated by different components into learning analytics is achieved through xAPI. Authentication and authorisation of all users of components can be done by means of SAML/VOOT.

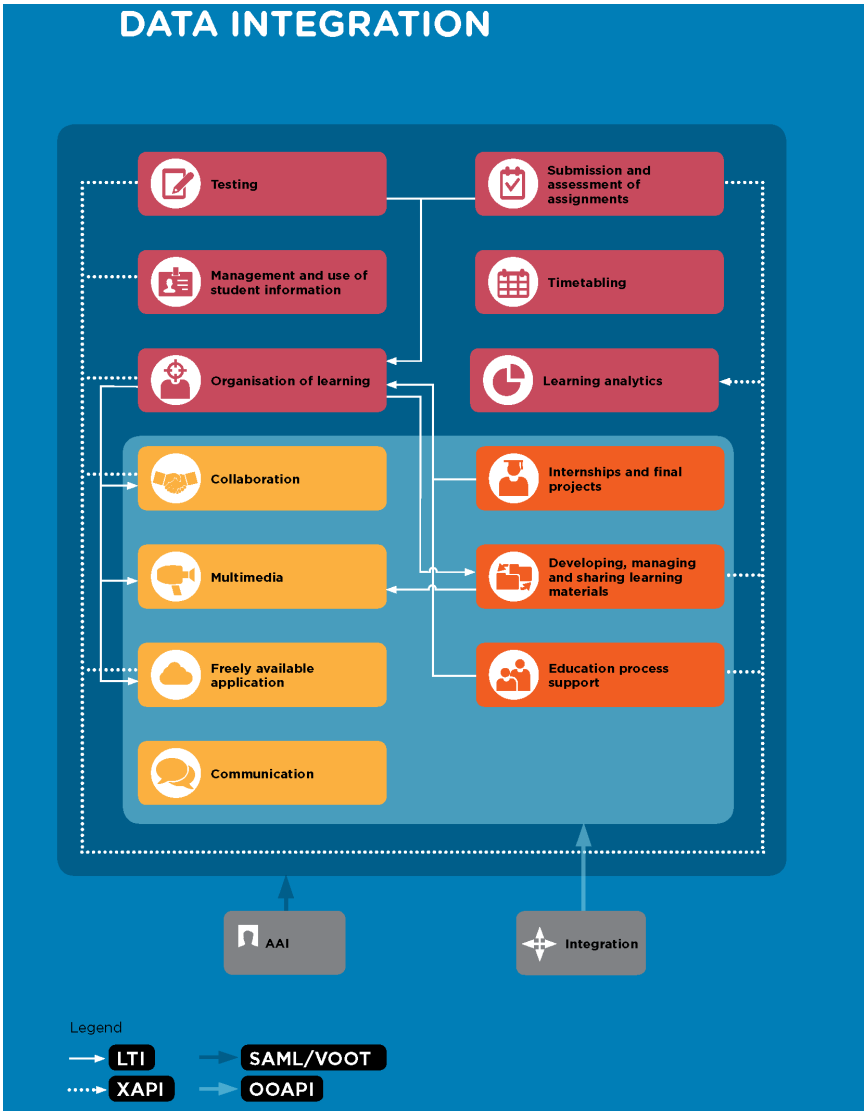


Figure 4: Data Integration

4.3. The role of standards in the digital learning environment

The use of standards ensures that the links between the various components are uniform. The standardisation of data exchange means that components can be used flexibly and are interchangeable. This gives institutions more freedom to select different components and suppliers. Standards also improve the accessibility of information. As data is displayed in a predictable manner, it is easier for new suppliers or even individual students to process information from the learning environment.

Thanks to this combination of flexible use of the components and improved access to information, students are able to exert greater influence on the architecture of their learning environment.

In practice, to make effective use of standards, we also need to bear in mind their maturity and (market) adoption. Because if a standard is used rarely or not at all, there is little chance that an institution will be able to find enough parties to exchange data with on the basis of this standard. The implementation of standards is not an easy process. It is often not just a question of technical interconnections, but also of processes and the handling of information.

The five standards of our functional model reflect the five dimensions of the DLE as proposed by ELI (2015) as follows:

1. LTI for Interoperability and Integration
2. LIS for Personalization
3. xAPI for Analytics, Advising, and Learning Assessment
4. SAML/VOOT for Collaboration
5. OOAPI for Accessibility and Universal Design

There is awareness of many of the specifications and standards within the higher education world. However, this knowledge and experience is not widely disseminated and is not always easy to locate. There is often experience with specific components, but a broader foundation is required in order to adopt an integrated approach.

To support institutions with their implementations of the digital learning environment, and to gai hands-on experience in an integrated approach, SURFnet developed a Demo DLE. The setup of this Demo DLE is described in the next paragraph.

5. DEMO DIGITAL LEARNING ENVIRONMENT

Many institutions endorse the idea of a DLE consisting of interchangeable and expandable components. In some settings, they already experiment with this thought. But when the learning management system has to to be replaced, most institutions still opt for an all-in-one system.
On the one hand, this is because there is nothing on the market that fully supports this idea. Vendors do offer (parts of) packages, but these are often not interoperable with other systems.
On the other hand, the requirements for the learning environment within the institutions are not well defined.
Institutions and suppliers must therefore be supported by both developing a vision of the modular digital learning environment and technical development. To match applications on the component model, the applications need to fulfill the main functionality of the components and need appropriate ways to interact with other components to exchange data. The Demo-DLE contributes to this matching because of the possibility to gain hands-on experience with the modular learning environment.

The setup of the Demo-DLE is designed for institutions as well as for vendors. It offers three instances for:

1) Teachers; teachers have to use the learning environment that is offered by the institution, which usually does not fully meet the needs of the teacher. Often, a teacher also wants to use tools on the course that are not available within the learning environment. An environment in which a teacher can choose the tools and applications that are important at the time, seems like a good solution here. The Demo-DLE helps teachers to gain experience with this process and SURF can explore whether this really fills a need.
2) People of the IT department managing a digital learning environment; When implementing a modular learning environment, integration issues play a major role. With the Demo-DLE, IT departments are able to do experiments with integration between the components.

3) Service providers; the success of a modular learning environment depends on the availability of tools that are actually integrated. The modular learning as a service provides vendors the opportunity to test wheter or not the integration works.

In the next couple of months, SURF invites institutes and service providers to experiment with the demo DLE. We expect that we can present the first results of the experiments during the conference.

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Herman van Dompseler is a freelance software architect and software designer for internet applications. He is most interested in the innovation cycle of a software product, working from ideas to product to data according to the lean startup methodology. For SURFnet he worked on several innovation projects the last years, with the topics: Learning Analytics, Digital Learning Environments, Groups Management and Streaming Video Services.