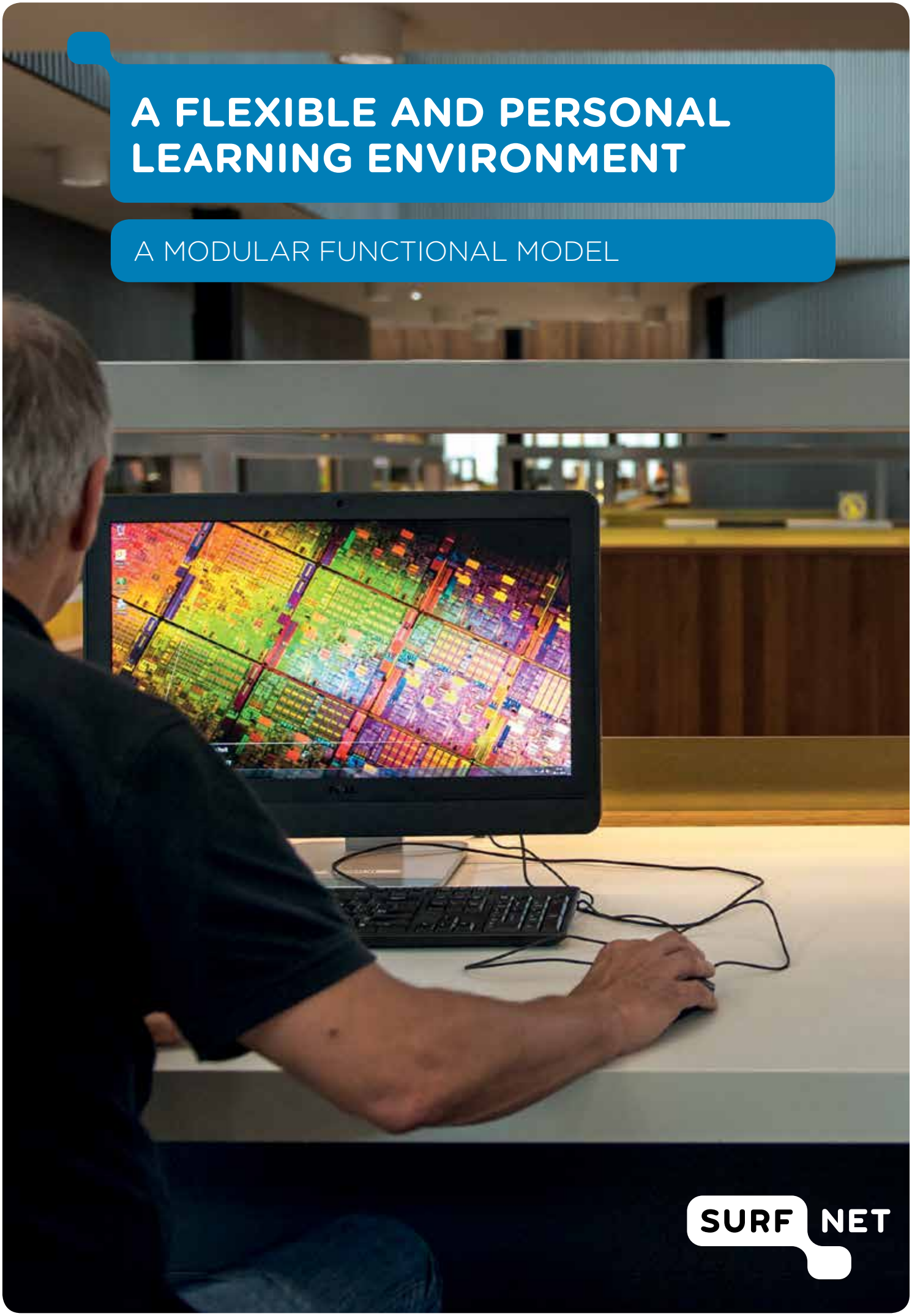
A FLEXIBLE AND PERSONAL LEARNING ENVIRONMENT

A MODULAR FUNCTIONAL MODEL



SURF NET

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INTRODUCTION AND BACKGROUND

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 environments.

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. Such an approach combines components (services, applications and ICT systems) as if they were pieces of LEGO to form a digital learning environment.

The document *A flexible and personal learning environment, from single components to an integrated digital learning environment*[1] describes the components that could comprise a digital learning environment. This includes components such as communication, collaboration or management of student data. Through components the various functions are interchangeable and expandable. As a result, the digital learning environment can be adapted to new developments in education and technology at any time.

In addition, standards, an integration infrastructure, and authorisation and authentication are required to enable the components to work together.

OBJECTIVE OF THIS PAPER

In this document, we examine the idea of a digital learning environment consisting of a range of different components. We seek answers to the following questions:

1. What data and functions are the components of a digital learning environment composed of?
2. What are likely configurations of these components?
3. What standards can be used for the exchange of data between components?

By responding to these questions, we demonstrate how the components within the digital learning environment are interlinked and able to interact. This allows us to develop a functional model of the digital learning environment.

The functional model describes the way in which the digital learning environment gives substance to educational functions within an institution and the relationships between them. Where possible, we make use of the business function model of the Higher Education Reference Architecture (HORA). We indicate which data the components exchange and the standards that are required to do so.

TARGET AUDIENCE

This document is intended for individuals concerned with the implementation of the digital learning environment. This includes (technical) project leaders, technical/functional support, information managers and architects. It offers insights into the further realisation of the digital learning environment and provides a number of points for discussion.

1. *https://www.surf.nl/binaries/content/assets/surf/en/knowledgebase/2016/memorandum-learning-environment_uk_web.pdf*

STRUCTURE

The relationships between the components of the digital learning environment can be regarded in a number of ways. We will adress two approaches: the approach based on the Higher Education Reference Architecture (HORA) and the approach based on the fortress metaphor.

Subsequently, Section 3 deals with the data flows. We discuss the standards used for each component as well as the incoming and outgoing data. We conclude with an overview of the challenges and points of interest for the standards used.

What are components?

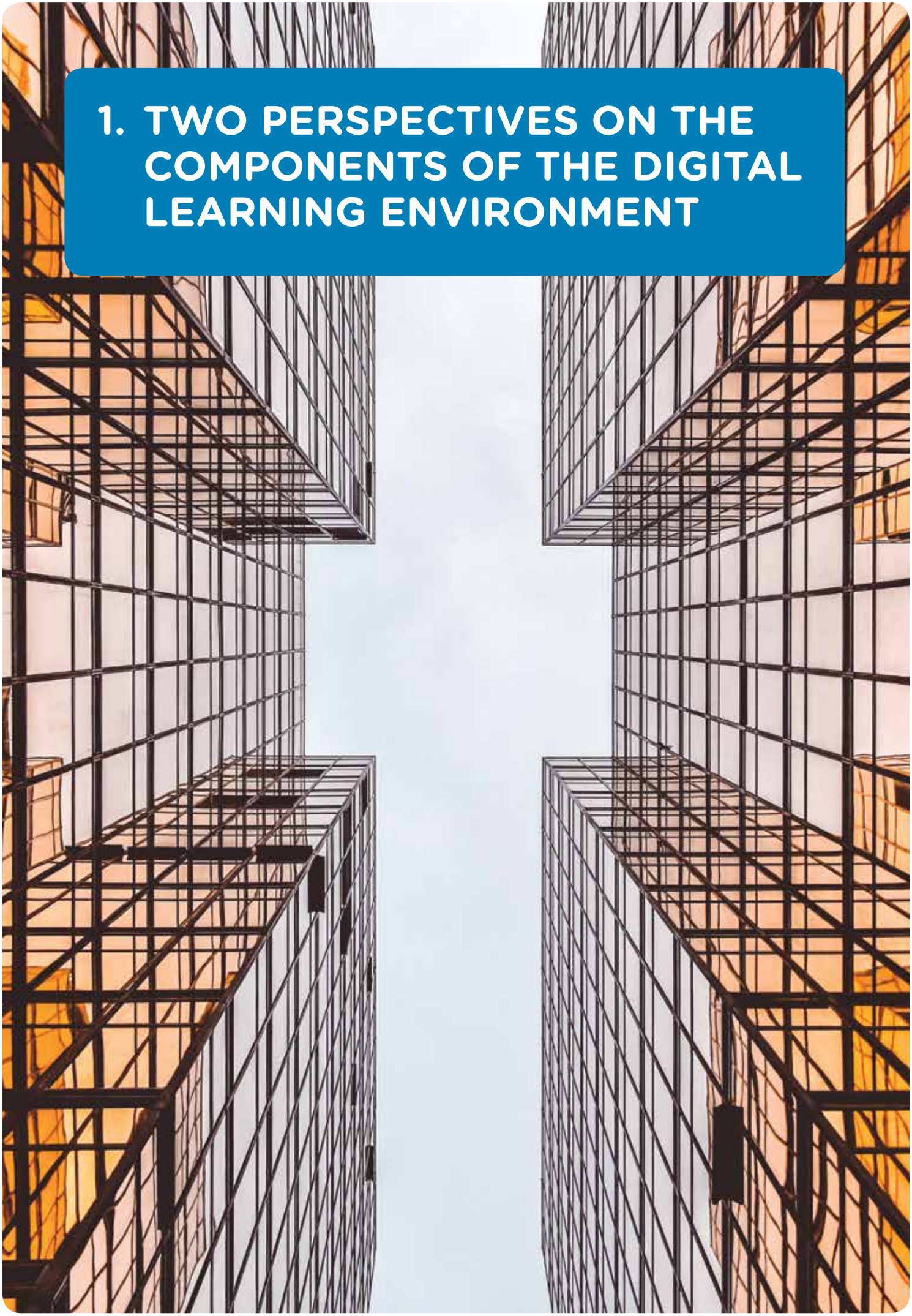
Components provide a function that allows a specific educational task to be performed properly. They provide functions such as communication, collaboration, testing, timetabling and the submission and assessment of assignments. These are the foundations upon which a digital learning environment is built.

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). A 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 the table below you will find an overview of the key functionality of each component. For more information, see Section 2.

Component	Key function
ORGANISATION OF LEARNING	Arrangement of learning activities
TESTING	Development of tests/assessments
SUBMISSION AND ASSESSMENT OF ASSIGNMENTS	To provide an upload tool
MANAGEMENT AND USE OF STUDENT INFORMATION	Management of student information
TIMETABLING	Support of the timetabling process
INTERNSHIPS AND FINAL PROJECTS	Managing internships and graduation
DEVELOPING, MANAGING AND SHARING LEARNING MATERIALS	Development of learning materials
EDUCATION PROCESS SUPPORT	To give feedback
LEARNING ANALYTICS	To record learning activity events
COMMUNICATION	To enable communication between lecturers, students and colleagues
COLLABORATION	To facilitate online collaboration
MULTIMEDIA	Management and playback of multimedia learning resources
FREELY AVAILABLE APPLICATIONS	External components that can supplement learning materials and the learning process

2. *http://www.wikixl.nl/wiki/hora/index.php/Hoofdpagina* (in Dutch)



1. TWO PERSPECTIVES ON THE COMPONENTS OF THE DIGITAL LEARNING ENVIRONMENT

Every educational institution has its own vision of education, and chooses itself which components it wants to include in its digital learning environment and in what way. That is why the organisation and format of the digital learning environment varies across institutions. In this document, we provide a detailed explanation of the components to help institutions make decisions regarding the digital learning environment.

The relationships between the components of the digital learning environment can be explained in several ways. This section focusses on two ways. Firstly, we use the HORA business function model to illustrate how the components support the business functions of an educational institution. We demonstrate how each component fits into the business function model. Where this is not (yet) possible, we place the component under a business function group to which it is able to make a contribution.

Secondly, we use the metaphor of the fortress and the open city[3]. This metaphor provides an insight into the degree of control and management an institution wishes to exert over its applications. We use this metaphor to explain how certain functions can be placed 'in the fortress' (high degree of control), whilst others can be located in the open city.

THE HORA BUSINESS FUNCTION MODEL

A business function model is a model of the business functions of an organisation. It describes what an organisation does without going into how it is achieved. The model clusters activities into logical units requiring similar knowledge and competences. A business function indicates where logical units and boundaries can be found in the organisation, processes and information services.

The business function model provides a list of functions that must be fulfilled within an institution. It is good to get an overview of the business functions which will be supported by the digital learning environment of the future. This helps us understand which functions are covered and where there might be gaps, thereby preventing any overlapping of functions.

When classifying the components under the HORA business function model, we apply the following thought process:

1. Educational development and testing are at the foundations of education. The institution expresses its vision on education in the educational approach it develops and the testing thereof. This is achieved, for example, through the use of the Teaching and Examination Regulations. The institution determines the curriculum and provides learning pathways. In addition, the institution provides resources for testing the progress of the student.
2. Educational support enables educational development, and lays the foundations to help shape the educational approach developed. It allows students to participate in education and ensures that results are recorded.
3. The aforementioned aspects are so crucial for educational institutions that they want to be able to maintain control over them. In addition, institutions are held accountable for the information in these components by external parties.
4. As regards the teaching, lecturers develop specific learning materials. Students engage in learning activities. These are very diverse, and vary in curriculums and learning pathways. Furthermore, lecturers guide students throughout this process, and help them improve where possible.
5. Providing and supervising the educational process are core activities of an institution. The results of the process and the evaluation thereof fall under centralised management within the institution.
6. Students and lecturers can also use applications that are available outside of the world of education (for example in support of the 'Communication' and 'Collaboration' components). It is not possible to know from the outset what these applications are, so institutions cannot directly control them. What they can do is facilitate the use of applications if they meet the right standards.

3. *https://www.eduGroups.nl/sites/VisieDLWO/DLWOWERKBOEK/WERKBOEK%20WIKI/Instrument%202%20-%20De%20metafoor%20van%20de%20burcht%20en%20de%20open%20stad.aspx* (in Dutch)

The digital learning environment supports the following business functions:
- Educational development and testing.
- The business functions that fall under the educational support cluster: recruitment, enrolment, education planning, timetabling, counselling of learners and certification.
- Education provision and guidance of learners.
- Other generic functions.

Business functions: educational development and testing

The business functions educational development and testing are at the heart of the educational organisation[4]. They involve the (re)development and evaluation of degree programmes, minors and units of study. Examining and evaluating the knowledge, understanding and skills of students for the purpose of producing a formal unit of study result[5] also falls under this category. These business functions determine the added value of an institution.

The following components are relevant to these business functions:
- Organisation of learning
- Testing
- Submission and assessment of assignments

Business functions from the educational support cluster

The educational support cluster covers business functions aimed at managing basic data and facilities in support of educational development and the provision of education. This includes enrolment, timetabling, certification, educational planning and participant counselling[6].

The following components are relevant to the business function of support:
- Management and use of student information
- Timetabling

Business functions: education provision and guidance of students

The provision of education refers to the actual (substantive) educational process. This is the daily routine of lecturers and students, whereby the student follows a course of study and the lecturer is there to supervise them. Many systems support the educational process. Various communication channels are used here, such as (peer) feedback, e-mail or other forms of communication. Guidance by lecturers can also be automatically supported by way of learning analytics.

The following components are important to the business functions education provision and supervision of learners:
- Developing, managing and sharing learning materials
- Education process support
- Learning analytics
- Internships and final projects

Other generic functions

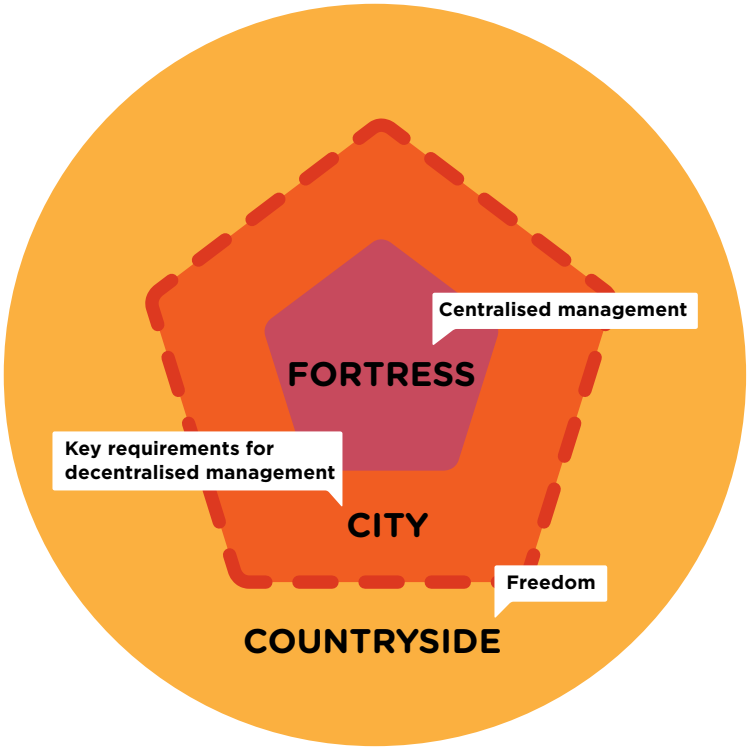
A number of components prove difficult to position in the HORA business function model. One reason for this is that these components contribute to several different business functions. That is why we have added a category entitled ‘generic functions’. The components in this group make it possible to communicate both within and outside of the institution, to collaborate and to make use of multimedia or externally developed learning activities. All of these components are able to support the components mentioned earlier by providing information and a number of functionalities.

The following components fall under this category:
- Communication
- Collaboration
- Multimedia
- Freely available applications

4. *http://www.wikixl.nl/wiki/hora/index.php/Bedrijfsfuncties_onderwijs* (in Dutch)
5. *http://www.wikixl.nl/wiki/hora/index.php/Onderwijseenheidresultaat* (in Dutch)
6. *http://www.wikixl.nl/wiki/hora/index.php/Bedrijfsfuncties_onderwijsondersteuning* (in Dutch)

THE METAPHOR OF THE FORTRESS AND THE OPEN CITY

In SURFnet's workbook 'Vision of DLWE', the metaphor of the fortress and the open city is developed. 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

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. 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.

The city

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.

The countryside

In the **COUNTRYSIDE** surrounding the fortress and the city, it is users themselves who decide what they do, with no interference from the institution.

Basic principles

This metaphor helps us to classify components. We allocate components to the fortress, the city or the countryside depending on the degree of control and authority over them. In doing so, we apply the following basic principles:

1. A component is formed on the basis of a logically grouped set of functions. Components are interchangeable and can be expandable.
2. Components are given a CIA score (Confidentiality, Integrity and Availability) on the basis of the CIA score of the business objects they cover. A business object is a set of data.

3. Components with a high CIA score are placed in the fortress. For these components, the institution attaches great importance to the confidentiality, integrity or availability of the business objects (data) they contain.
4. Components should be able to exchange data reliably, using (open) standards and APIs where possible.
5. The functional model presented is based on best practices. Institutions are able to make their own choices as to the structure, and can therefore opt for a different model if they wish.

Information security

The components are given a CIA classification. This classification indicates the desired degree of confidentiality (C), integrity (I) and availability (A) for a component. This gives us an idea of the information security measures that are required when selecting a particular component. The CIA classifications have been derived from the HORA[7] where possible. Institutions must translate this generic CIA classification into their own measures.

A CIA classification consists of three scores: a C score, an I score and an A score. Each score can be high, medium or low. The confidentiality score is primarily determined by personal data protection requirements. Data required in order to provide a good education receive a high I score. Data that is key to the day-to-day running of an institution receive a high A score.

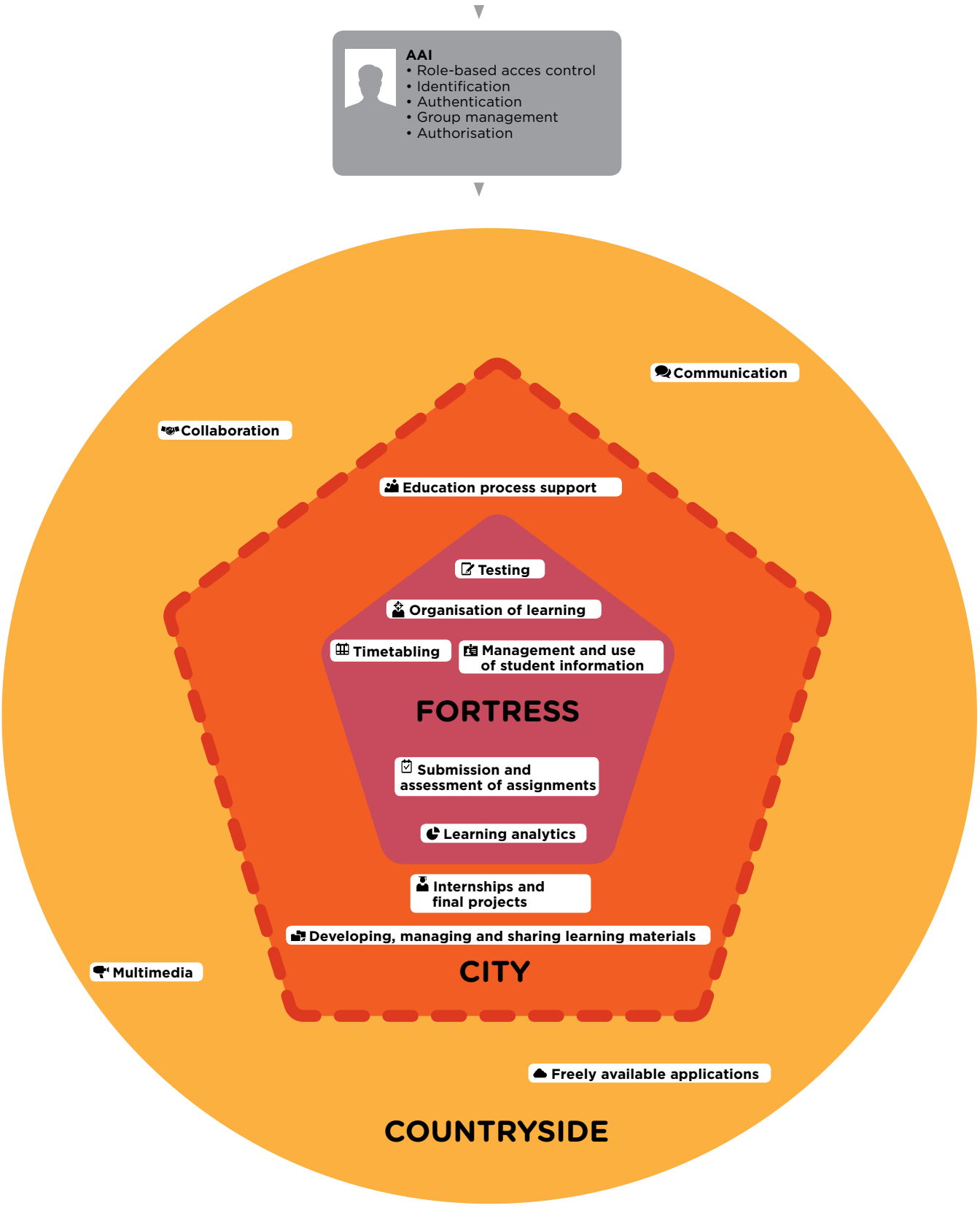
The table below indicates the CIA classification for each component and the most important business object. The CIA classification was calculated by taking the highest C, I or A score for the business objects for which the component is responsible. The most important piece of data is the business object with the highest CIA score for each particular component.

	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	-

This CIA classification can help to allocate the components under the fortress/city/countryside metaphor. 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.

7. *http://www.wikixl.nl/wiki/hora/index.php/BIV_classificaties* (in Dutch)
8. This is a business object that does not appear in the HORA.
9. Here, we deviate from the HORA classification because the emphasis in this component lies on the performance/progress monitoring of the graduation assignment (the actual evaluation takes place within the component 'Submission and assessment of assignments').

The figure below illustrates where the components are situated in the fortress metaphor.



Authentication and authorisation infrastructure (AAI)
One prerequisite for making the the various components act as one cohesive unit is a good authentication and authorisation infrastructure (AAI). This infrastructure allows the user access to the components in a uniform manner (authentication), and ensures that the role of the user is known within each of the components (authorisation). Depending on the form of membership of a particular group, a user can be accorded more or fewer rights within a component. AAI allows personal characteristics to be reused in the learning environment. This means characteristics such as identity, attributes and group information. By using personal characteristics, we can tailor the learning environment to each individual lecturer or student.

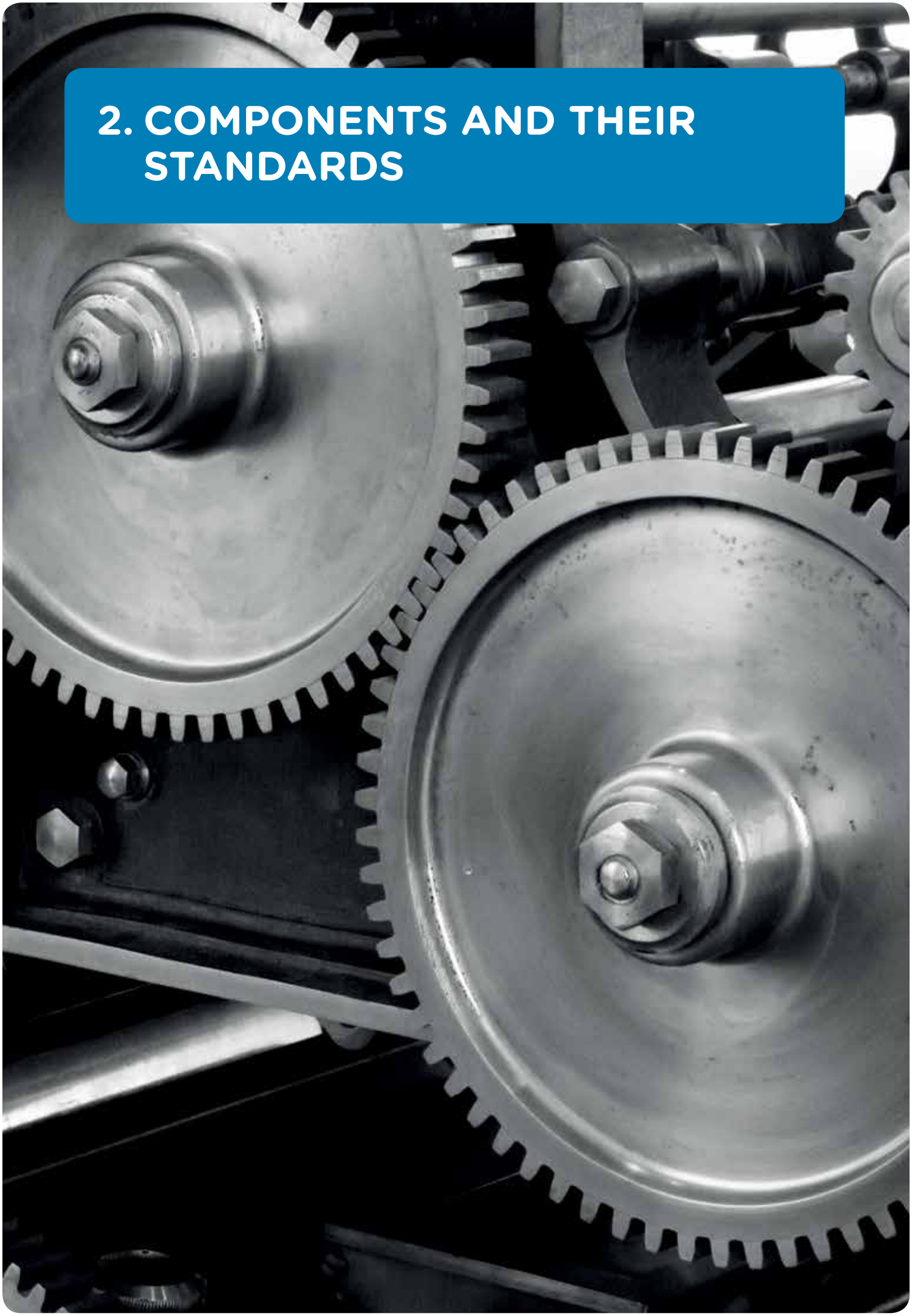
When describing the components, we assume the user has a 'passport' allowing them to participate in the learning environment. This means the user is known to the institution and within the component (whether using SURFconext or not). This can also be seen in the fortress metaphor diagram on page 12. There, the AAI is not included as a component, but instead is located outside of the illustration. The AAI is a condition for use of the components in the digital learning environment.

THE COMPONENTS HAVE BEEN CLASSIFIED: WHAT'S NEXT?

The classification of the components according to the HORA and the fortress metaphor gives us an idea of where the components fit into the IT landscape of an institution. In the previous section, we looked at the CIA classification and the functions that need to be supported.

In the following section, we look at the way in which the components are connected and able to interact. For each component, we indicate which data can flow in and out and what standards apply to this exchange of data. This in turn results in the creation of an exemplary implementation model that can be used when establishing a digital learning environment.

2. COMPONENTS AND THEIR STANDARDS



Components consist of a number of functionalities, and these communicate not just with other components, but also with each other. In order to structure and streamline this communication, it is a good idea to use standards. In this section, we provide an overview of the components, their functionalities and the relevant standards.

READING GUIDE

A table is included for each component. This table illustrates where each component stands in relation to other components. In addition, it indicates which data the component generates and uses and what standards can be applied for this purpose.

In addition, we give an overview of the business objects (dataset) used for each component. Each type of data has been assigned a CIA score. The CIA score has been determined using the HORA, and business objects that are not yet included in the HORA are marked with *. The scores can either be (H) high, (M) medium, (L) low or (P) public. The component is responsible for the data for which the CIA score is marked in bold and blue. The CIA score of the component is indicated at the bottom of the table. This corresponds to the highest score of the business objects (data) **bold and blue**, i.e. the data for which the component is responsible. An example is provided below:

Business objects/data	Confidentiality	Integrity	Availability
Uses object A	H	H	M
Responsible for object B	**P**	**H**	**H**
Uses object C	L	M	M
Responsible for object D	**L**	**H**	**M**
CIA score	L	H	H

H = High M = Medium L = Low P = Public

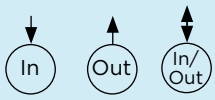
Interpretation of a component

Data/ business objects — The data that is exchanged, based on the HORA business objects model.

Standards — **The most relevant standards for the transfer of data within the institution.**

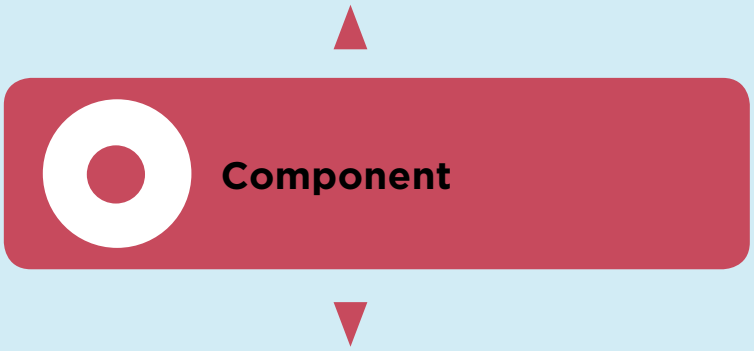
Component — Indicates with which other components the component in question exchanges data. Individual institutions may choose different options.

Direction — Indicates whether the data is incoming or outgoing.



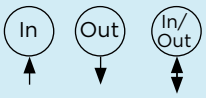
Indicates that this link primarily involves the exchange of back office data (sometimes in bulk). System integration can take place via a protected network.

System integration



Data integration

Direction — Indicates whether the data is incoming or outgoing.



indicates that this link primarily involves the exchange of data for the purpose of making a particular functionality possible. Data integration often takes place via public networks.

Component — Indicates with which other components the component in question exchanges data. Individual institutions may choose different options.

Standards — **The most relevant standards for the transfer of data within the institution.**

Data/ business objects — The data that is exchanged, based on the HORA business objects model.

COMPONENT
ORGANISATION OF LEARNING

Description

The component 'Organisation of learning' allows groups of students to make use of the learning materials selected for them by lecturers. In addition, this may involve content or other components such as a multimedia object. It does not matter whether these are run within the institution or by a publisher of educational material, for example.

The component 'Organisation of learning' is often combined with a Learning Management System (LMS).[10] Educational standards make it possible to exchange material between systems or to present an external playback environment in a LMS. The component 'Organisation of learning' makes use of the following business objects. The component is responsible for documenting learning activities (indicated in **bold and blue** in the table below).

Business objects	Confidentiality	Integrity	Availability
Minor	P	H	M
Unit of study	P	H	M
Curriculum	L	H	M
Degree programme	P	H	M
Class group	L	M	M
Participant	H	H	M
Learning group	L	M	L
Learning materials	L	M	M
Learning activity	**L**	**H**	**M**
Learning activity event*	L	M	L
Context*	L	M	M
News items*	P	L	L
Learning analytics reporting*	H	M	M
CIA score	L	H	M

* = Not in HORA H = High M = Medium L = Low P = Public

Position in the Flexible and Personal Learning Environment (FPLE)

Due to the high integrity score for information about learning activities, we have placed the LMS in the fortress, where learning is coordinated. However, this component can make use of functionalities run by an external content provider operating in the city or in the countryside.

The data concerning the curriculum structure and the (groups of) students are mostly obtained via the Student Information System (SIS).

Functional description

The component 'Organisation of learning' comprises the following functionalities:

1. Arranging content
2. Organising students into groups
3. Providing access to content
4. Processing the results of learning analytics

1. Arranging content

Each degree programme is split into smaller units such as minors and subjects. This division into units (the curriculum) is often recorded in the SIS. The curriculum structure is also required to be able to organise learning. Educators link learning materials to each of these units. This allows the materials to be used within the LMS by students participating in these units. The learning materials are developed by the institution itself or drawn from a content provider. In the latter case, the materials can also be used via an external tool.

Standards

Via IMS LIS (Learning Information Services), the curriculum data from the SIS can be sent to the LMS. The application profile CPS (Course Planning and Scheduling) is available specifically for this purpose. This can also be done via OneRoster.

SCORM (Sharable Content Object Reference Model) and IMS CC (Common Cartridge) are competing standards for describing, organising and exchanging educational material. Most LMSs can import material from both standards.

IMS LTI (Learning Tools Interoperability) makes it possible to present an external tool as a playback environment within a LMS. The ePUB standard allows content (not only text but also video and similar) to be automatically adapted for use, for example, with different e-reader formats. A more comprehensive version is currently being developed with IMS: EDUPUB.

2. Group management

To make teaching feasible for lecturers, students are split into groups. This may mean sub-groups of exisiting groups from the SIS, or simply combinations of existing groups. The HORA distinguishes between learning groups and class groups. Class groups are groups following a particular learning unit. Participants in such a group have enrolled in this unit of study, and are scheduled as a group. Learning groups are groups that are formed in connection with a project or collaborative learning arrangement. Learning groups are often dynamic, and vary from assignment to assignment.

10. For the sake of readability, we refer in some cases to a SIS or LMS as these are applications that are frequently used for the 'Organisation of learning' and 'Recording and managing student data' components. In fact, what we mean is 'applications responsible for Organisation of learning' and 'applications responsible for recording and managing student data'.

Standards
In the SIS, it is possible to indicate which (groups of) students are participating in particular sections of the curriculum. Via IMS LIS/CPS or OneRoster, the data of these students, class groups or learning groups can be uploaded to the LMS. IMS LIS/CPS or OneRoster are primarily used to create links between systems. The other standards in this paragraph are primarily intended for data links.

Group management is not limited to these formal groups in existing systems. It is also possible to form ad-hoc/project groups. For this purpose, groups can also be managed centrally in a group management application such as GroupHub. This allows groups to be used in a number of different systems within the institution.

By using authentication, for example via SAML and LDAP, it is ensured that the students selected in the SIS have access to the learning materials. Via SURFconext, this can also be done for external content providers using SAML and VOOT. With the VOOT protocol, group data from an institution's SIS can be used to provide access to an external tool via SURFconext Teams[11].

3. Access to content
In the SIS, employees (e.g. student services) can select students or class groups for a specific course. This selection determines which students receive access to specific material. These (groups of) students are then able to use the material once they have logged in to the institution system.

Standards
Employees indicate in the SIS which (groups of) students are participating in particular sections of the curriculum. Via IMS LIS/CPS or OneRoster, the data of these students, class groups or learning groups, can be transferred to the LMS. These employees can then create a link to the educational material for that section of the curriculum.
IMS LTI makes it possible to present an external tool as a playback environment within a LMS.

4. Processing the results of learning analytics
The actions undertaken by students during their learning activities are recorded in a central system called a Learning Record Store. These actions can be used to improve students' learning process.

Standards
The results of learning analytics can be consulted using IMS Caliper or xAPI. These results can be used to visualise and flag areas of teaching that are in need of improvement.

>> See the next page for an overview of standards and dataflow of this component.

11. *https://www.surf.nl/en/services-and-products/surfconext/index.html*

Overview of standards dataflow of Organisation of learning

Data	• Unit of study • Minor • Curriculum • Degree programme	• Class group • Participant • Learning group	• Class group • Participant • Learning group
Standards	IMS LIS (CPS)	IMS LIS	IMS LIS
Component	Management and use of student information	Management and use of student information	AAI
Direction	In	In/Out	Out

System integration

Organisation of learning

Data integration

Direction	In	Out	In	Out	In	Out	In
Component	Developing, managing and sharing learning materials	Learning analytics	Developing, managing and sharing learning materials	Developing, managing and sharing learning materials Education process support Internships and final projects Multimedia Collaboration Freely available applications	Developing, managing and sharing learning materials Education process support Internships and final projects Multimedia Collaboration Freely available applications	Relevant component	Learning analytics
Standards	SCORM IMS CC	xAPI IMS CALIPER	ePUB IMS eduPUB	IMS LTI	IMS LTI	OOAPI	xAPI IMS CALIPER IMS LTI
Data	• Learning materials • Learning activity	• Learning activity events	• Learning materials	• Participant • Context	• Learning activity	• Groups • News items	• Learning analytics reporting


In
Out
In
Testing
Communication
Multimedia
Submission and assessment of assignments
IMS LTI
Miscellaneous: see 'Communication'
Miscellaneous: see 'Multimedia'
• Test activity
• Test result
• Miscellaneous: see 'Communication'
• Miscellaneous: see 'Multimedia'

COMPONENT **TESTING**

Description

The 'Testing' component provides support for two different forms of testing: summative testing and formative testing. Summative tests determine whether a student has met the requirements of a unit of study, and often result in a numerical grade. Formative tests help to gain an idea of gaps in a student's knowledge or understanding. Feedback is an important element of testing, as this makes adaptive learning possible. In the case of formative testing, additional learning materials can be attached directly to feedback. This component records the test result, the testing activity and the testing material. In addition, the time at which the students may complete their test is documented. These business objects are indicated in **bold and blue** in the table below.

Business objects	Confidentiality	Integrity	Availability
Class group	L	M	M
Participant	H	H	M
Learning group	L	M	L
Test result	**M**	**H**	**L**
Time of test activity*	**P**	**M**	**L**
Test activity	**L**	**H**	**M**
Test material	**H**	**H**	**H**
Learning activity event*	L	M	L
CIA score	H	H	H

* = Not in HORA H = High M = Medium L = Low P = Public

Position in the Flexible and Personal Learning Environment (FPLE)

When determining where to place a component in the fortress metaphor, the information used or generated in the component is used as a guide. Although the two different types of testing do not place the same requirements on the management and security of data, the component as a whole is still regarded as a fortress component due to the high CIA classification of all three of the sub-components.

Functional description

Testing not only covers the participation of students in tests, but also the creation and playback environment of the test. The following functions fall under the 'Testing' component:

1. Developing a test in the authoring environment
2. Taking a test and viewing the result in a playback environment
3. Saving test elements in an item bank
4. Analysing the use of the tests

1. Authoring environment

The authoring environment is where lecturers develop their test material. From here, they can also exchange test items and item banks with colleagues within and outside of the institution. In general, this exchange usually takes place within one field of study. Collaboration between institutions is increasing, for example on national testing and question databases for teacher training, healthcare, mathematics and statistics.

Standards

There is not really a standard for developing tests. There are a number of options for exchanging questions that have already been developed via IMS QTI (Question and Test Interoperability). In addition, IMS LIS/OneRoster can be used as a tool for exchanging personal data between the SIS and the test environment. This is mainly useful for linking (groups of) students to existing tests.

2. Playback environment

The playback environment enables students to view their test(s) and any available results.

Standards

IMS LIS/OneRoster creates a link to other systems in the fortress, such as the SIS. This is how the playback environment obtains data about the class group or students and sends out test results. LTI allows the playback environment to be presented within a different environment or allows for the use of a different test environment to be executed form the component 'organisation of learning'. This can be the LMS or another environment of choice.

The student is given the option to start a test. If they activate the test, a message is sent to the playback environment via LTI. LTI then signals that an enrolled student has logged in and prepares the test items. Subsequently, the student takes the test in the playback environment. The test result is then reported back to the SIS using the IMS LIS/OneRoster standard. If the student exits the session, the data is saved.

In order to communicate the date and time when the test was taken, the playback environment can use iCal or IMS CPS. In order to create a link with the 'Timetabling' component, a special application profile is available from LIS: IMS CPS. This profile determines the way in which course information and timetabling can be structured within the LIS format.

3. Item bank

The item bank contains test items that have been developed. The playback environment obtains data from the item bank on the basis of the test matrices available there.

Standards

IMS QTI links the item banks to the playback environment as well as to other item banks if required. The items are described using metadata based on Learning Object Metadata (LOM). OAI-PMH is aimed at importing teaching material from repositories. SRU/SRW does the same thing but from the Internet.

4. Analysis tool

Lecturers can analyse completed tests to compare groups, individuals or test items. Psychometric analyses provide information about the manner in which students go through a test, for example by highlighting which questions they spend the most time on, and which test items they initially skip.

Standards

Results Reporting from IMS QTI is suitable for analysing test results.

>> See the next page for an overview of standards and dataflow of this component.

Overview of standards and dataflow of Testing

Data	• Class group • Participant • Learning group	• Test result	• Time of test activity
Standard	IMS LIS	IMS LIS	IMS LIS (CPS) iCAL
Component	Management and use of student information	Management and use of student information	Timetabling
Direction	In	Out	Out

System integration

Testing

Data integration

Direction	In	Out	In/Out	Out
Component	AAI	Organisation of learning	Testing	Learning analytics
Standard	SAML/VOOT IMS LTI	IMS LTI	IMS QTI	xAPI IMS Caliper
Data	• Participant • Learning group	• Test activity • Test result	• Test material	• Learning activity events

COMPONENT
SUBMISSION AND ASSESSMENT OF ASSIGNMENTS

Description

In order to assess students' level of knowledge, more than just testing is required. Students must also produce assignments, either alone or in groups, and submit these for evaluation. For institutions, it is becoming increasingly important to ensure that both the assignment and the evaluation thereof are correctly recorded and archived. The watchful eye of accreditation committees is an additional incentive to include this task in a properly functioning digital environment. Such an environment can facilitate the entire process surrounding assignments. This process covers the designation of evaluators, the communication of deadlines, the uploading of the work produced by the student and the evaluation procedure. A plagiarism check is another essential component of this process.

The component 'Submission and assessment of assignments' is responsible for recording test results and (evaluated) pieces of work. In addition, it is possible to determine within this component the deadline by which students must submit their assignments. These business objects are indicated in **bold and blue** in the table below.

Business objects	Confidentiality	Integrity	Availability
Class group	L	M	M
Participant	H	H	M
Learning group	L	M	L
Evaluator/employee	H	H	M
Test result	**M**	**H**	**L**
Time of test activity*	**P**	**M**	**L**
Evaluated assignments/ pieces of work	**M**	**H**	**L**
Learning activity	L	H	M
CIA score	M	H	L

* = Not in HORA H = High M = Medium L = Low P = Public

Position in the Flexible and Personal Learning Environment (FPLE)

The component 'Submission and assessment of assignments' is similar to the component 'Testing'. Both components make use of information over which centralised control is exercised. Most of the data in this component must be saved securely and have a high CIA classification when it comes to integrity. This applies to evaluations, test results and assignments. For this reason, we have placed this component in the fortress. However, when it comes to the briefing and submission of assignments, it is possible to create a link with tools that lecturers (city) and students (countryside) are free to choose themselves.

Functional description

In order to provide support for the process surrounding the Submission and assessment of assignments, we differentiate between five different functions:

1. Submission of a piece of work or assignment via an upload tool
2. Management of the submission process
3. Plagiarism checks
4. Sending back evaluations
5. Management of results and documents

1. Upload tool

Students can submit a piece of work using an upload tool. The lecturer specifies which (groups of) students must submit an assignment, for example in the SIS. Subsequently, the students can log in and gain access to the tool for the period indicated. The upload tool can be added as an extra feature on an online forum, for example. Of course, this forum will have to support the relevant standard (LTI).

Standards

IMS LIS/OneRoster can be used to transfer the group composition from the SIS to the upload tool. IMS LTI allows identification and other data to be exchanged with an 'external' tool. IMS LTI can also be used to launch an institution's own tool in an external environment.

2. Management of the submission and evaluation process

All assignments have deadlines. Students must submit their work in time and, in turn, lecturers must provide their evaluation or feedback in time. In this process, good communication is crucial, for example when setting and informing students of deadlines. It is also possible for these to be automatically entered in students' calendars. If it looks like the student is likely to fail to meet the deadline, they can automatically be sent a warning.

Standards

Deadlines can be notified via iCal or IMS CPS (Course Planning and Scheduling). The CPS application profile of IMS LIS (Learning Information Services) provides the option of also offering information about the type of assignment in addition to the deadline. This ensures that the link between the components is as rich as possible. iCal is primarily suitable for communication with end user applications.

3. Plagiarism checks
Plagiarism checks are crucial in the world of education today. Degree programmes often have their own tools that automatically check all work submitted. Sometimes, students can also carry out a plagiarism check themselves. This allows them to check whether their co-authors (or they) have overused citations.

Standards
There are no standards for plagiarism checks. In practice, a link is created with tooling for plagiarism checks on the basis of IMS LTI. The results of the check are then sent to the LMS using IMS LTI Outcomes.

4. Sending back an evaluation
The evaluation and any feedback from the lecturer must be sent back to the student. In some cases, the assignment is also (initially) evaluated by fellow students. In both cases, the feedback is linked to the document.
Upon receiving the evaluation, the student is given the opportunity to appeal against it.

Standards
It is possible to send back evaluations and feedback to the same environment in which the assignment was submitted via LTI. Alternatively, the evaluation can be sent to the SIS via IMS LIS/OneRoster (without feedback). In this case, the student is only able to see their grade.

The relationship between deadlines, actual submission times and the processing of feedback is also taken into account by learning analytics: this is indicative of students' learning strategies. These kinds of events can be automatically interconnected using IMS Caliper or xAPI.

5. Document management
As mentioned previously, pieces of work need to be properly archived. There are even legal regulations in this regard[12] [13]. For this purpose, institutions can use a document management system or the SIS.

Standards
CMIS is the standard for exchanging this kind of unstructured data in an accessible manner.

12. *https://zoek.officielebekendmakingen.nl/kst-33472-3.html* (in Dutch)
13. *https://www.surf.nl/binaries/content/assets/surf/nl/kennisbank/2012/SURFdirect+rapport+Persoonsgegevens+studenten.pdf* (in Dutch)

Overview of standards and dataflow of Submission and assessment of assignments

Data	• Class group • Participant • Learning group	• Test result	• Evaluated documents	• Time of test activity
Standards	IMS LIS	IMS LIS	CMIS	IMS LIS (CPS) iCAL
Component	Management and use of student information	Management and use of student information	Management and use of student information	Timetabling
Direction	In	Out	Out	Out

System integration

Submission and assessment of assignments

Data integration

Direction	In	Out	Out
Component	AAI	Organisation of learning	Learning analytics
Standards	SAML/VOOT IMS LTI	IMS LTI	xAPI IMS Caliper
Data	• Participant • Learning group	• Test result	• Learning activity events

COMPONENT
MANAGEMENT AND USE OF STUDENT INFORMATION

Description

The use of student information is one of the core activities of an educational institution. A Student Information System (SIS) is used for this purpose. This SIS must communicate with other systems both for the purpose of inputting and modifying personal data and for saving and sharing study progress and similar information.

In addition, student information is often the source information used when composing groups and carrying out deployment planning for degree programmes. The component 'Management and use of student information' makes use of the following business objects. The component is responsible for the business objects indicated in **bold and blue**.

Business objects	Confidentiality	Integrity	Availability
Participant	**H**	**H**	**M**
Enrolment*	**H**	**H**	**M**
Unit of study	**P**	**H**	**M**
Minor	**P**	**H**	**M**
Curriculum	**L**	**H**	**M**
Degree programme	**P**	**H**	**M**
Class group	**L**	**M**	**M**
Learning group	L	M	L
Test result	**M**	**H**	**L**
Unit of study result	**M**	**H**	**L**
Employee	**H**	**H**	**M**
Evaluated documents/ pieces of work	**M**	**H**	**L**
Diploma/certification document	**L**	**H**	**L**
Grading list*	**L**	**H**	**L**
Study progress*	**H**	**H**	**M**
Exam results	**M**	**H**	**L**
Course information*	**P**	**H**	**M**
Event*	P	L	L
CIA score	H	H	M

* = Not in HORA H = High M = Medium L = Low P = Public

Position in the Flexible and Personal Learning Environment (FPLE)

Student information includes a large amount of important administrative data for the management of an institution. The data places high demands on availability, integrity and confidentiality requirements, which means this component can definitively be placed in the fortress. Student information is a source for many other systems using student data as well as the curriculum. In order to retrieve this source data securely, it is important to create a 'port' to this information. The Open Education API (OOAPI) can play an important part in this.

Functional description

There are various standards for managing, processing and retrieving student information, educational data, group information, grades and progress. IMS LIS/ OneRoster and OOAPI are the two standards that are most relevant here. The component 'Management and use of student information' has the following functionalities:

1. Management of student information
2. Curriculum/study guide/course catalog
3. Group registration
4. Attendance recording
5. Grade registration
6. Progress recording
7. Document management

1. Management of student information

Enrolments are transmitted to institutions via Studielink, and the same applies to any changes in data. However, data can also be modified manually within the SIS. Students can make changes to their data via self-service pages.

Standards

Studielink has its own standards for messaging. For other changes, IMS LIS/OneRoster can be used.

2. Curriculum/study guide/course catalog

The various SISs save the curriculum in their system in different ways. These data can be retrieved by applications such as the LMS and by external parties. They are also available to schedulers, who select the most suitable lecturer for each part of the curriculum.

Standards

In the Netherlands, the Higher Education Data Exchange (HODEX) standard was developed to describe degree programmes, open days and other marketing activities carried out by institutions. This allows them to be compared, for example, on course selection websites. In the area of degree programme information, IMS CPS (Course Planning and Scheduling) can also be used. No other standard than HODEX is known for marketing information.

There is no general standard that is used for deployment planning; instead, a self-developed tool in the SIS is used (for Osiris that is PTD). It is also possible to use a CSV file to exchange this kind of data.

3. Group registration
The student population is split into cohorts in the SIS. In addition, groups are formed on the basis of enrolments for particular subjects or other relevant student information. Subsequently, smaller class groups are formed using the group structure created using the timetabling application.

Standards
The IMS LIS/OneRoster standard is used for the exchange of information about (the composition of) groups. As with the component 'Organisation of learning' the best way to share groupings is to use a group management tool. This means that other systems can also use the groupings. It is possible to use the VOOT standard for this purpose.

4. Attendance recording
For some study modules, attendance is compulsory. In this case, the lecturer checks whether everyone is actually present.

Standards
These data are sent to the SIS using IMS LIS/OneRoster.

5. Grade registration
Lecturers enter grades for tests and other learning activities into a testing or learning tool. They are then sent from this tool to the SIS. There, they can also be entered manually. Successful completion of a module is also recorded in the SIS.

Standards
The lecturer enters their grades into the test application (which may be external). IMS LIS/OneRoster is the standard for the transfer of data to the SIS.
In the case of an external application, this data is forwarded to the SIS via the LMS using IMS LTI. With these two standards, test results can be exchanged between a test system and the SIS.

With OOAPI, the grade and other information from the SIS can be presented in the student's personal environment, such as a smartphone app.

6. Progress recording
A lecturer or mentor can see in the SIS how much progress a student has made in a particular degree programme. On the basis of this, they can hold a progress meeting to talk about further study plans. Learning analytics is closely related to this.

The current trend is to combine progress data and other student activities in a 'learning record store'. This helps to better monitor students' progress.

Standards
IMS CPS indicates which modules the student has participated in.

OOAPI and IMS Caliper or xAPI allow progress information to be sent to the student's personal environment or to learning analytics.

7. Document management
Diplomas and other relevant documents are generated in the SIS. They can be saved in the SIS or in a document archive (DMS). The data is forwarded to the DUO[14] Diploma Register.

Standards
CMIS (Content Management Interoperability Services) is the standard for exchanging unstructured data in an accessible manner.

>> See the next page for an overview of standards and dataflow of this component.

14. *Dutch Education Executive Agency.*

Overview of standards and dataflow of Management and use of student information

Data	• Participant • Enrolment	• Unit of study • Minor • Curriculum • Degree programme	• Participant • Class group • Learning group	• Participant • Class group • Learning group	• Test result	• Employee • Class group • Learning group	• Evaluated documents
Standard	IMS LIS / studielink	IMS LIS (CPS)	IMS LIS	IMS LIS	IMS LIS	Maatwerk	CMIS
Component	External: Studielink	Organisation of learning	Organisation of learning Timetabling Testing Submission and assessment of assignments	Organisation of learning Timetabling	Testing Submission and assessment of assignments	Management and use of student information External: deployment planning	Submission and assessment of assignments Developing, managing and sharing learning materials Education process support
Direction	In	Out	Out	In	In	Out	In

System integration

Management and use of student information

Data integration

Direction	Out	Out	Out
Component	Relevant component	Relevant component	Learning analytics
Standard	OOAPI	HODEX OOAPI	xAPI IMS CALIPER
Data	• Study progress • Exam results • Course information • Class groups	• Minor • Curriculum • Degree programme • Event	• Test result • Educational unit result

- Diploma
- Grading list

- Class group
- Participant
- Learning group

CMIS

IMS LIS

Management and use of student information

AAI

COMPONENT **TIMETABLING**

Description

Timetabling involves distributing time and facilities across lecturers and students. It is not easy to precisely meet everyone's needs. This challenge is becoming even tougher now that education is increasingly having to be focused on student demand and not supply on the part of institutions. Such personal learning pathways require the system to be extra flexible. The component 'Timetabling' makes use of the following business objects. The component is responsible for the business objects indicated in **bold and blue**.

Business objects	Confidentiality	Integrity	Availability
Class group	**L**	**M**	**M**
Learning group	L	M	L
Participant	H	H	M
Deployment planning	L	M	L
Employee	H	H	M
Availability of rooms and facilities*	P	M	M
Reservation of rooms and facilities*	P	M	M
Date and time of tests*	P	M	M
Availability of employees*	L	M	M
Timetable	**L**	**M**	**H**
CIA score	L	M	H

* = Not in HORA H = High M = Medium L = Low P = Public

Position in the Flexible and Personal Learning Environment (FPLE)

Timetabling manifests itself in two different ways:
- the timetabling process;
- the timetable as a result of this process.

The timetabling process makes use of data from the fortress. In addition, the availability requirements are high and management of timetabling is a centralised responsibility. As a result, the data under the 'Timetabling' component are placed in the fortress. The timetable itself is made available in students' personal environments, i.e. in the city and the countryside.

Functional description

The 'Timetabling' component supports the timetabling process. In this component, many different sources are combined to ensure correct planning. We distinguish between two functions:
1. Timetabling (as a process)
2. Display of/communication regarding the timetable

1. Timetabling

The curriculum defines activities. During duty planning, lecturers are then selected for these activities. The available rooms and educational facilities such as projectors are also determined. This supply must be matched with student demand. This means that there must be a distribution of class groups in space and time. In future, this process may become even more complex. Ideally, individual students will be able to reserve their own class times via the LMS.

Standards

IMS LIS/OneRoster is used to obtain the data for the (groups of) students from the SIS, and IMS CPS is used for the curriculum data. iCal or IMS CPS can be used to retrieve any fixed test times from the 'Testing' component.

The data concerning the available rooms is usually obtained via customised links or CSV files from the facility management system. The data from lecturers comes from the HRM system. Often, duty planning is entered manually too: this can be done using a module in the SIS (such as PTD in the case of Osiris) or using a CSV file.

2. Display of/communication regarding the timetable

A timetable only works if all those concerned are aware of its content. That is why lecturers and students must be able to use and view timetabling data. The timetable can include both individual activities and group timetables.

Standards

IMS LIS/OneRoster can be used to obtain timetabling data from the SIS. OOAPI and iCal are both suitable standards for displaying timetabling data in a presentation layer.

Overview of standards and dataflow of Timetabling

Data	• Class group • Participant • Learning group	• Deployment planning • Class group • Employees	• Availability of rooms and other educational facilities • Reservations	• Time of test activity	• Availability of employees	• Class group • Participant • Learning group
Standard	IMS LIS	Customised	Customised	IMS LIS (CPS) iCAL	Customised	IMS LIS
Component	Management and use of student information	Management and use of student information	External: facilities	Testing	External: HRM	Management and use of student information
Direction	In	In	In/Out	In	In	Out

System integration

Timetabling

Data integration

Direction	Out
Component	Relevant component
Standard	iCAL OOAPI
Data	• Timetable

COMPONENT
LEARNING ANALYTICS

Description

How do individual students work and what results does this produce? Several components of the digital learning environment produce relevant data about learning processes. Using standards allows this data to be compiled, recorded and analysed in the 'Learning analytics' component. This component also includes applications for visualising and presenting the analyses.

Learning analytics is the key to improving education. It helps individual students to monitor their own progress. In addition, it indicates how effective certain learning resources and working methods are, and enables lecturers to better recognise individual learning needs on the part of students more quickly. For this purpose, standards must be applied consistently in a digital learning environment.

The component 'Learning analytics' makes use of the following business objects. The component is responsible for the business objects indicated in **bold and blue**.

Business objects	Confidentiality	Integrity	Availability
Learning activity events*	**L**	**M**	**L**
Test result	M	H	L
Unit of study result	M	H	L
Learning analytics reporting*	**H**	**M**	**M**
Progress*	L	M	M
Participant	H	H	M
Context*	L	M	M
CIA score	H	M	M

* = Not in HORA H = High M = Medium L = Low P = Public

Position in the Flexible and Personal Learning Environment (FPLE)

Learning analytics takes place throughout the entire education process. As the information involved is private and sensitive, the data are recorded in a Learning Records Store (LRS) in the fortress. The reports can be presented in the personal digital environment of a lecturer or student.

Unlike other components in the fortress, 'Learning analytics' is not subject to system integration as it retrieves its data via the front end.

Functional description

Learning analytics starts with the standardised recording of a student's learning activities in a LRS. Visualising the data from this LRS can provide information about a student or course. The data can be analysed using an Analytics Processor. Lecturers or educational developers can then use this analysis as a basis for action or predictions. As a result, the following two functionalities are supported:

1. Learning Record Store/Learning Record Warehouse
2. Learning Analytics Processor

1. Learning Record Store/Learning Record Warehouse

This is where the data, collected for learning analytics, from the other components and the SIS is stored. These are measurements of the study behaviour of students and the results they obtain.

Standards

IMS Caliper and xAPI (Experience API) allow the behaviour of a student during learning activities to be described and communicated.

2. Learning Analytics Processor

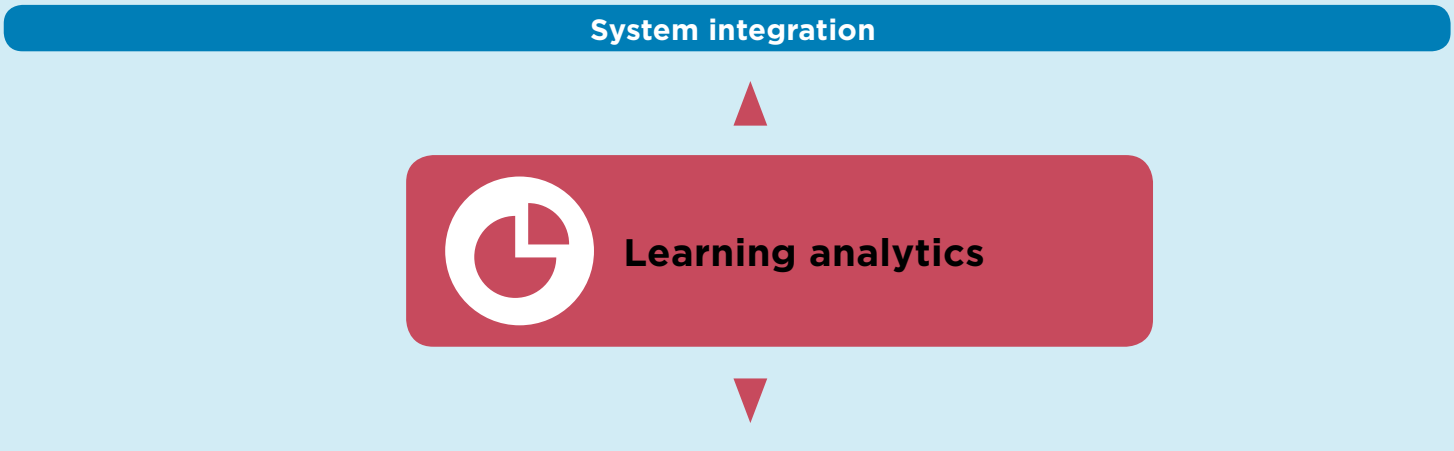
This is where the collected data is analysed.

Standards

IMS Caliper and xAPI allow the behaviour of a student during learning activities to be described and communicated. In addition, they can also be used to display information collected about the behaviour of multiple students during a learning activity.

With OOAPI, grades and other information from the SIS can be presented in the student's personal environment, such as a smartphone app.
LTI allows learning analytics reports to be presented in the LMS or the personal environment of a student or lecturer.

Overview of standards and dataflow of Learning analytics



Data integration

Direction	In	In	Out	Out	Out	In
Component	Organisation of learning Testing Submission and assessment of assignments Education process support Developing, managing and sharing learning materials Collaboration Freely available applications	Management and use of student information	Relevant component	Relevant component	Organisation of learning Education process support	AAI
Standard	xAPI IMS Caliper	xAPI IMS Caliper	xAPI IMS Caliper	OOAPI	IMS LTI	SAML/VOOT IMS LTI
Data	• Learning activity events	• Test result • Unit of study result	• Learning analytics reporting	• Progress	• Learning analytics reporting	• Participant • Context

COMPONENT
DEVELOPING, MANAGING AND SHARING LEARNING MATERIALS

Description

All kinds of materials are used in support of students' learning process: texts, images, audio, video and also tests. It is important for valuable material to be stored and made available for (re-)use within and outside of the institution.

The most suitable way of doing this is to store the material in a repository. This is a digital storage place where all materials are accompanied by internationally standardised metadata. This means they can be quickly found and selected (including using search engines such as Google). Institutions use repositories to make their research publications publicly available. Educational material is also made available in this way.

A repository can be shared by multiple institutions. One example of this is Sharekit, which was developed by SURF so that universities of applied sciences without their own repository can store knowledge products and learning materials.

The component 'Developing, managing and sharing learning materials' makes use of the following business objects. The component is responsible for the business objects indicated in **bold and blue**.

Business objects	Confidentiality	Integrity	Availability
Content/educational material*	**L**	**M**	**M**
Learning materials	**L**	**M**	**M**
Learning activity (without testing)*	**L**	**M**	**M**
Participant	H	H	M
Context*	L	M	M
LA reporting*	H	M	M
Addition of metadata to learning materials*	**L**	**M**	**M**
Search query*	P	L	L
URL result set*	P	L	L
CIA score	L	M	M

* = Not in HORA H = High M = Medium L = Low P = Public

Position in the Flexible and Personal Learning Environment (FPLE)

We regard the development of learning materials as an educational activity, and this takes place in the city. However, if an institution opts to provide learning materials using a repository, it must be placed in the fortress. This is because a repository falls under the centralised policy of the institution.

Placement in the fortress is also necessary if the learning materials used must be available for assessment by the education inspectorate. This is particularly important for universities of applied sciences.

Functional description

The component 'Developing, managing and sharing learning materials' consists of the following three functionalities.

1. Developing learning materials
2. Saving and storing learning materials
3. Sharing learning materials

1. Developing learning materials

Institutions often develop their own learning materials. These might take the form of documents, images or presentations. However, there are many more possibilities: videoclips, web lectures, serious games and so on. A LMS often has built-in tools for this purpose. There are also standalone authoring tools. In addition, educational publishers are starting to publish more and more digital learning materials.

Standards

SCORM and IMS CC are similar standards for describing, organising and exchanging educational material.

The ePUB standard allows content (such as text or video) to be automatically adapted to the medium on which it is being displayed. A more comprehensive version is currently being developed with IMS: EDUPUB.

2. Saving and managing materials

Self-developed learning materials must be made available for re-use. For this purpose, they are tagged with metadata that clearly describe the form and content. In order to manage a document, it is primarily important to clarify what the latest version is.

Standards

NL-LOM is the Dutch version of an international standard used to describe educational content using metadata. Dublin Core is another metadata standard. Other relevant standards are IMS-CC, SCORM and ePUB. CMIS is the standard used for exchanging unstructured data in an accessible manner.

3. Sharing learning materials

It is of course ideal to be able to re-use effective learning materials, including outside of the institution. This is usually done using a repository.

Standards

SRU/SRW are standards for web services used to find material online. OAI-PMH (Open Archives Initiative Protocol for Metadata Harvesting) is a protocol used for exchanging the metadata of materials in repositories. IMS LTI allows an external tool to be presented within a LMS as a play-back environment. Finally, the standards IMS-CC, SCORM and ePUB are also relevant here.

>> See the next page for an overview of standards and dataflow of this component.

Overview of standards and dataflow of Developing, managing and sharing learning materials

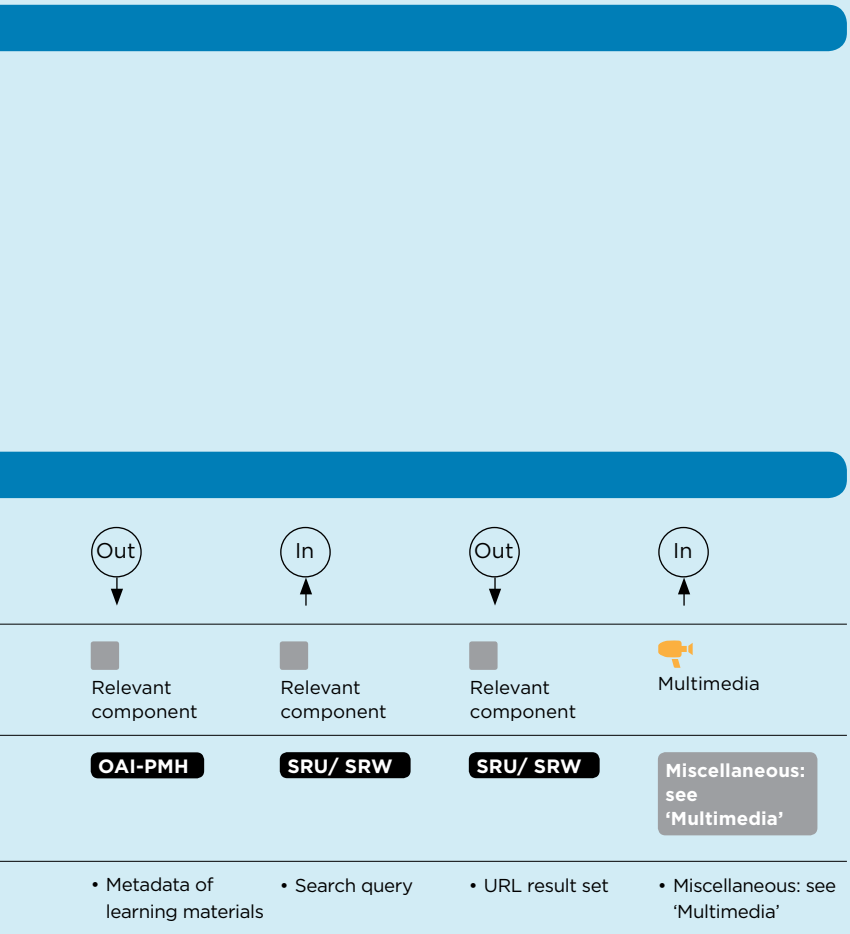
Data	• Content	• Evaluated documents
Standard	CMIS	CMIS
Component	Developing, managing and sharing learning materials	Management and use of student information
Direction	In/Out	Out

System integration

Developing, managing and sharing learning materials

Data integration

Direction	Out	In	Out	Out	Out	Out	Out
Component	Organisation of learning	AAI	Organisation of learning	Learning analytics	Organisation of learning	Organisation of learning	Relevant component
Standard	SCORM	SAML/VOOT IMS LTI	IMS LTI	xAPI IMS CALIPER	IMS CC	ePUB IMS eduPUB	NL LOM Dublin core
Data	• Learning materials • Learning activity	• Participant • Context	• Learning activity	• Learning activity events	• Learning materials • Learning activity	• Learning materials	• Metadata of learning materials


Out
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Out
In
Relevant component
Relevant component
Relevant component
Multimedia
OAI-PMH
SRU/ SRW
SRU/ SRW
Miscellaneous: see 'Multimedia'
• Metadata of learning materials
• Search query
• URL result set
• Miscellaneous: see 'Multimedia'

COMPONENT
EDUCATION PROCESS SUPPORT

Description

Coaching students throughout their learning process, requires more than only interaction during tests and assignments. This is often done using a digital portfolio. In this portfolio, a student's development process is planned and documented and feedback is given. The portfolio contains for example internship reports and pieces of work. The use of portfolios appears to be on the rise in higher education. A survey of educational professionals indicated that portfolios are primarily used within higher professional education and university-based vocational training.
According to the Educause report[15], the best solution would be a set of applications and platforms offering students integrated portfolio tools. This would allow them to present an overview of everything they have learned and produced. The component 'Education process support' makes use of the following business objects. The component is responsible for the business objects indicated in **bold and blue**.

Business objects	Confidentiality	Integrity	Availability
Evaluated portfolios*	H	H	M
Progress (on the basis of learning activities without testing)*	**L**	**M**	**M**
Learning activity events*	L	M	L
Learning analytics reporting*	H	M	M
Participant	H	H	M
Context*	L	M	M
Results	M	H	L
Credits/Badges (on the basis of results)	M	H	L
CIA score	L	M	M

* = Not in HORA H = High M = Medium L = Low P = Public

Position in the Flexible and Personal Learning Environment (FPLE)

Learning activities take place in the city, as does the support thereof. The data itself receives a medium CIA classification. However, the certification documents for supervision purposes must be securely archived in the fortress. This applies in particular to certification documents concerning the learning pathways followed, including exemptions. This is because institutions want to have control over this documentation, and are held accountable for it.

Functional description

The educational process can be supported and supervised in a variety of ways. There are systems for providing feedback, for saving documents and for enabling communication between lecturers and students. In the component 'Education process support', we have identified the following functionalities:

1. Feedback
2. Peer feedback
3. Communication
4. Digital portfolio

1. Feedback

Lecturers can provide feedback in a number of ways. They often do so using a feedback tool or by annotating documents.

Standards
Both IMS Caliper and xAPI (Experience API) allow a student's learning activities and actions to be collected and communicated in the form of 'events'. A student action can be recorded, for example, if they read the lecturer's feedback. IMS LTI allows this component to be presented as a playback environment within a LMS.

2. Peer feedback

Fellow students can also provide feedback, for example on an online forum by way of discussions regarding a group assignment.

Standards
For this functionality, no standards are identified yet. Student activities on forums are certainly an important source of information for learning analytics (also see the explanation for 1. Feedback).

3. Communication

Lecturers and students also provide feedback via e-mail, social media, Skype and other generic communication channels. These are dealt with under the component 'Communication' (page 44).

Standards
See the 'Communication' component (page 44).

4. Digital portfolio

Lecturer feedback and results can be transmitted to the 'Learning analytics' component. They can also be immediately archived in the SIS or a document management system (DMS). Exemption requests and authorisations are performed via the SIS, after which the learning pathway is adjusted in the portfolio. IMS LTI allows a portfolio to be presented within a LMS as a playback environment.

Standards
The standard NEN 2035 E-portfolio NL can be used for digital portfolios. This is based on an application profile from the IMS ePortfolio standard. CMIS (Content Management Interoperability Services) can be used to exchange unstructured data in an accessible manner. IMS LIS/OneRoster is used to send data to the SIS, and can also be used to retrieve data from the SIS.

15. *https://library.educause.edu/-/media/files/library/2015/4/eli3035-pdf.pdf*

Overview of standards and dataflow of Education process support

Data	• Evaluated documents (portfolios)
Standard	CMIS
Component	Management and use of student information
Direction	Out

System integration

Education process support

Data integration

Direction	Out	In	In	Out	In	In	Out
Component	Learning analytics	Learning analytics	AAI	Organisation of learning	External	External: employers	Internship and graduation assignments External: employers
Standard	xAPI IMS CALIPER	xAPI IMS CALIPER IMS LTI	SAML/VOOT IMS LTI	IMS LTI	Open Badges	NEN 2035 E-portfolio NL	NEN 2035 E-portfolio NL
Data	• Learning activity events	• Learning analytics reporting	• Participant • Context	• Learning activity	• Results • Credits	• Portfolio	• Portfolio

COMPONENT
INTERNSHIPS AND FINAL PROJECTS

Description

Internships and/or final projects are regarded as a special way of coaching the educational process and testing students. The content of an internship or graduation assignment must tally as closely as possible with the programme of study chosen by the student. In many cases, external parties are involved, the student carries out learning activities over a longer period and documents must be properly stored.

The resulting reports and evaluations are also crucial to the centralised management of the institution, which is why they are located under the component 'Submission and assessment of assignments'. We have placed the relationship management in connection with collaboration with external organisations under the CRM of the institution. That is why relationship management does not form part of this component.

The component 'Internships and final projects' makes use of the following business objects. The component is responsible for the business objects indicated in **bold and blue**.

Business objects	Confidentiality	Integrity	Availability
Class group	L	M	M
Learning group	L	M	L
Participant	H	H	M
Test result	M	H	L
Business/organisation	L	L	L
Internship/graduation organisation	L	L	L
Internship/graduation assignment	L	H	L
Progress (on the basis of learning activities without testing)*	**L**	**M**	**M**
Internship contract*	L	M	L
Portfolio*	H	H	M
CIA score	L	M	M

* = Not in HORA H = High M = Medium L = Low P = Public

Position in the Flexible and Personal Learning Environment (FPLE)

The component 'Internships and final projects' is partially comparable to 'Education process support'. 'Internships and final projects' describes the content and execution of internships and final projects. As such, it does not cover internship or research reports; these contain information over which the institution exercises centralised management, just like the evaluations of these reports.

This is because they contain private and sensitive information and the institution must be able to demonstrate accountability for them when the student obtains a diploma.

Functional description

The component 'Internships and final projects' comprises the following functionalities:

1. Matching a student with an internship
2. Feedback and communication

1. Matching a student with an internship/ assignment

In order to find a suitable internship, an overview of available internships and/or assignments can be offered to eligible students. Alternatively, students themselves can put forward a research proposal. In addition, the skills profile in their portfolio can provide a basis for finding a good match.

Standards

VOOT can be used to retrieve the correct (groups of) students from the authorisation and authentication infrastructure. With OOAPI, information about available internships and assignments can be presented in the personal environment of the student or lecturer in the form of news items.
The standard NEN 2035 E-portfolio NL can be used for describing skills in portfolios. This is based on an application profile of the IMS ePortfolio standard.
IMS LTI allows this component to be presented as a playback environment within a LMS.

2. Feedback and communication

During their final projects or internship, a student has regular contact with their coaches at the educational institution and the company in question. Coaches can provide feedback in a number of ways. They often do this by annotating documents or using e-mail, social media, Skype and other generic communication channels. IMS LTI allows this component to be presented as a playback environment within a LMS.

Standards

See the 'Communication' component on page 44.

Overview of standards and dataflow of Internships and final projects

Data	• Company data • Internship/ graduation organisation • Internship/ graduation assignment
Standard	Customised
Component	External: CRM/ internship sites
Direction	In

System integration

Internships and final projects

Data integration

Direction	Out	In	In	Out
Component	Relevant component	Education process support	AAI	Organisation of learning
Standard	OOAPI	NEN 2035 E-portfolio NL	SAML/VOOT IMS LTI	IMS LTI
Data	• Internship/ graduation assignment • Internship/ graduation organisation in the form of news items	• Portfolio	• Participant • Context	• Learning activity

COMPONENT **COMMUNICATION**

Description

Without communication, there can be no education. Most communication is one on one between the lecturer and the student and among lecturers or students. Lecturers and other colleagues must also be able to contact groups of students quickly. The component 'Communication' makes use of the following business objects, and is responsible for the business objects indicated in **bold and blue**. The business objects may vary in terms of integrity and confidentiality depending on their content, which is why they have not been allocated a CIA score.

Business objects	Confidentiality	Integrity	Availability
Calendar item*	-	-	-
Voicemail*	-	-	-
News item*	**P**	**L**	**L**
Video conference*	-	-	-
Learning group	L	M	L
Context*	L	M	M
Message*	-	-	-
CIA score	L	M	M
(Regarded as the Education process support component but not confidential)			

* = Not in HORA H = High M = Medium L = Low P = Public

Position in the Flexible and Personal Learning Environment (FPLE)

Students are used to bring their own means of communication with them to the institution, for example their own e-mail account and mobile telephone. Communication takes place in the countryside, outside the jurisdiction of the institution. The institution does not record any data. Where this is necessary, the result of the communication (feedback, for example) is housed under another component.

Functional description

Endless forms of communication are possible. Below we have listed a number of key functionalities:

1. E-mail/calendar
2. Forums
3. Social media
4. Voice
5. Video conferencing
6. News channels

1. E-mail/calendar

An e-mail address and calendar invitations with the institution's domain name is a useful online proof of identity both within and outside of an institution.

Standards

When sending an e-mail with calendar information, a number of different protocols are combined, such as SMTP.

2. Forums

Many subjects have their own forum where learners can view and comment on their assignments.

Standards

IRC (Internet Relay Chat) can be used for messaging, both in the forum and one-on-one.

3. Social media

Students and lecturers are often so familiar with using social media in their daily lives that they also use these channels in an educational context. This communication takes place out of view of the institution. Social media can, however, be integrated into the LMS, for example by using Yammer for a particular course.

Standards

Currently, there are no standards available for this.

4. Voice

Telephone contact – especially internationally – between lecturers and students is taking place via Skype or other conference call tools increasingly often.

Standards

SIP is the standard behind 'telephone communication' via Internet (not only voice but also video). An additional advantage of this is that the institution domain name of the caller is displayed. This demonstrates greater credibility vis-à-vis internship companies and other external parties.

5. Video conferencing

This application now has its own fully-fledged standards. It provides opportunities for richer communication, especially when it is possible to edit documents at the same time.

Standards

SIP is the standard for voice communication. H.263 is the standard for data compression during video conferencing. Using the WebRTC standard, video conferencing can take place directly between web browsers without the need for extra software.

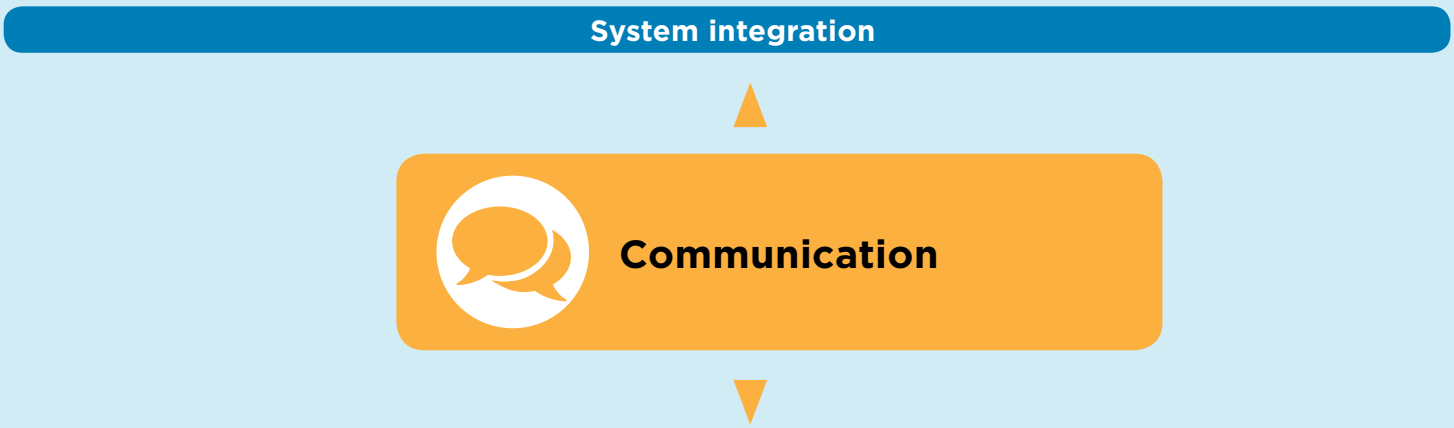
6. News channels

News channels can provide individual students or groups of students with relevant information.

Standards

News items are displayed in the student's portal using OOAPI.

Overview of standards and dataflow of Communication



Data integration

Direction	In	Out	In	In	In	In	In
Component	Organisation of learning	Relevant component	Organisation of learning	Organisation of learning	AAI	Organisation of learning	Organisation of learning
Standard	iCAL	OOAPI	SIP	H263 Web RTC	SAML/VOOT	Email	IRC
Data	• Calendar	• News item	• Voice	• Video conferentie	• Learning group • Context	• Message	• Message

COMPONENT **COLLABORATION**

Description

Collaboration is becoming increasingly important to the learning process. When working together, students can get more out of a subject, thereby increasing the depth of their knowledge. Students can work together on finding content, co-author a document or provide one another with feedback. In addition, more collaboration is taking place between students and experts from outside of their own institution.

For all of these activities, good group management is required. MOOCs and learning communities can help here. The 'Collaboration' component makes use of the following business objects. The component is responsible for the business objects indicated in **bold and blue**.

Business objects	Confidentiality	Integrity	Availability
Learning activity events*	L	M	L
Learning group	L	M	M
Context*	L	M	M
Participant	H	H	M
Learning activity	L	H	M
CIA score	L	M	M
(Regarded as the Education process support component but not confidential)			

* = Not in HORA H = High M = Medium L = Low P = Public

Position in the Flexible and Personal Learning Environment (FPLE)

In order to be able to learn from one another, collaboration is required. Students often organise their own forms of collaboration, for example using Google Drive or OneNote. Collaboration takes place in an open environment, and therefore in the countryside. Institutions can also opt to provide a collaboration environment, such as Google Apps for Education or Office 365.

Functional description

There are many possible forms of collaboration, and just as many functionalities. For institutions, it is essential that the management of collaborative groups is as simple as possible. The most common functionalities are:

1. Collaboration on assignments
2. Annotation/feedback
3. Collaboration with external parties

1. Collaboration on assignments

Sometimes, students form their own groups for working on an assignment; in other cases, the lecturer decides on the group composition. Students sometimes use a shared folder as a collaboration platform, but also often resort to Google Docs or Office 365. They simply invite one another to become shared users.

Standards

With the VOOT protocol, group data from an institution's SIS can also be used in order to provide students with access to an external tool. This can be done using SURFconext Teams or a group management application such as GroupHUB. IMS LTI allows an external tool to be presented within a LMS. IMS Caliper and xAPI allow a student's learning activities to be described and communicated, for example to learning analytics.

2. Annotation/feedback

Feedback from fellow students or lecturers is placed in the document for which the feedback has been provided.

Standards

As explained previously, VOOT, LTI, IMS Caliper and xAPI can be used.

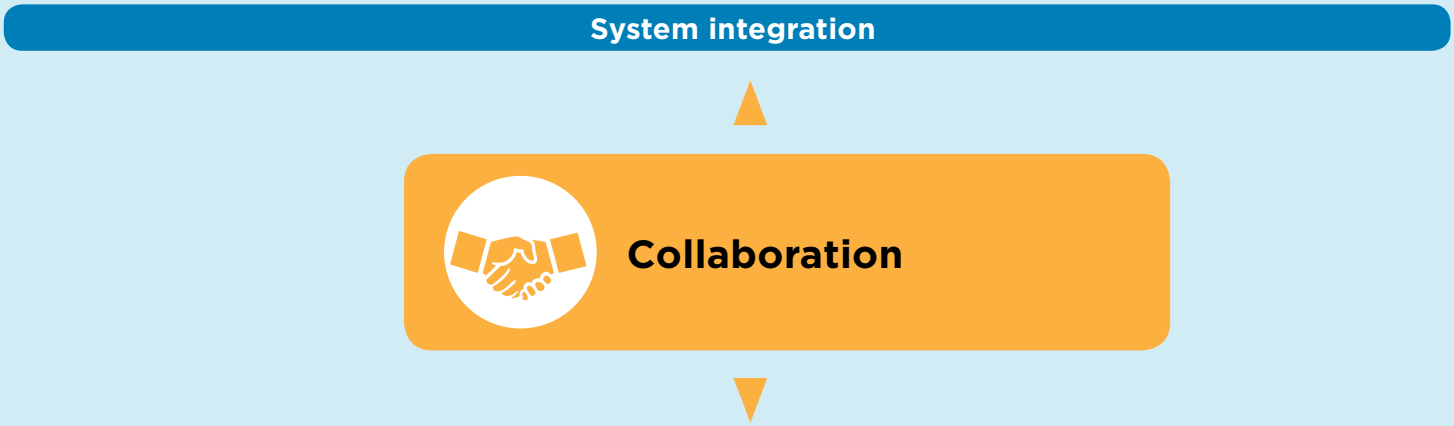
3. Collaboration with external parties

In certain projects, students work together with an external expert, for example if they are using a research tool.

Standards

As mentioned, VOOT can be used as a standard here.

Overview of standards and dataflow of Collaboration



Data integration

Direction	Out	In	In	Out
Component	Learning analytics	AAI	AAI	Organisation of learning
Standard	xAPI IMS CALIPER	SAML/VOOT	IMS LTI	IMS LTI
Data	• Learning activity events	• Learning group • Context	• Participant • Context	• Learning activity

COMPONENT **MULTIMEDIA**

Description

Video and other media are being used increasingly often in education. Education is not only being enhanced by videos, but also by virtual reality (VR), augmented reality (AR), games, computer-aided design (CAD), 3D and other multimedia objects. In some cases, such games partially replace traditional educational methods, and the lecturer can provide the student with specific, tailored support.

The 'Multimedia' component uses the following business objects. The component is responsible for the business objects indicated in **bold and blue**. No CIA score can be given for some of these business objects as this depends on the content of the business object.

Business objects	Confidentiality	Integrity	Availability
Addition of metadata to videos*	-	-	-
2D and 3D graphics and animations*	-	-	-
Video*	-	-	-
Learning activity	L	H	M
Learning materials	**L**	**M**	**M**
CIA score *(regarded as learning material)*	L	M	M

* = Not in HORA H = High M = Medium L = Low P = Public

Position in the Flexible and Personal Learning Environment (FPLE)

Multimedia objects often come from external sources. As a result, this activity takes place in the countryside. Sometimes, a multimedia object must be managed in the fortress. This is the case for research results or other confidential information, for example.

Functional description

The 'Multimedia' component is characterised by the fact that it is comprised of innovative objects, meaning that in many cases the standards have not yet fully matured. Multimedia objects in the learning process are often developed using a software development kit (SDK) and a tool that makes use of this kit. In addition, a specific client is usually required in order to share these objects.

Virtual reality is a good example of a fledgling multimedia tool. Oculus uses its own SDK, but there is also Open VR and OSVR. Different headsets are required for different formats. As for video, there are standards in place (see 2. Sharing).

Although the business objects vary significantly, they are used for the same functionalities:

1. Development
2. Sharing

1. Development

A picture is worth a thousand words. Complex objects and videos allow educational institutions to help students understand how various concepts work. Specialist software is available for developing video and complex objects such as VR, AR and simulations. It is possible for the objects developed to be tagged with metadata, either automatically or otherwise, so that they are easy to find again.

Standards

MPEG7 is the standard for describing and searching for multimedia content. Open Graphics Library (OpenGL) is an API for creating 2D and 3D graphics.

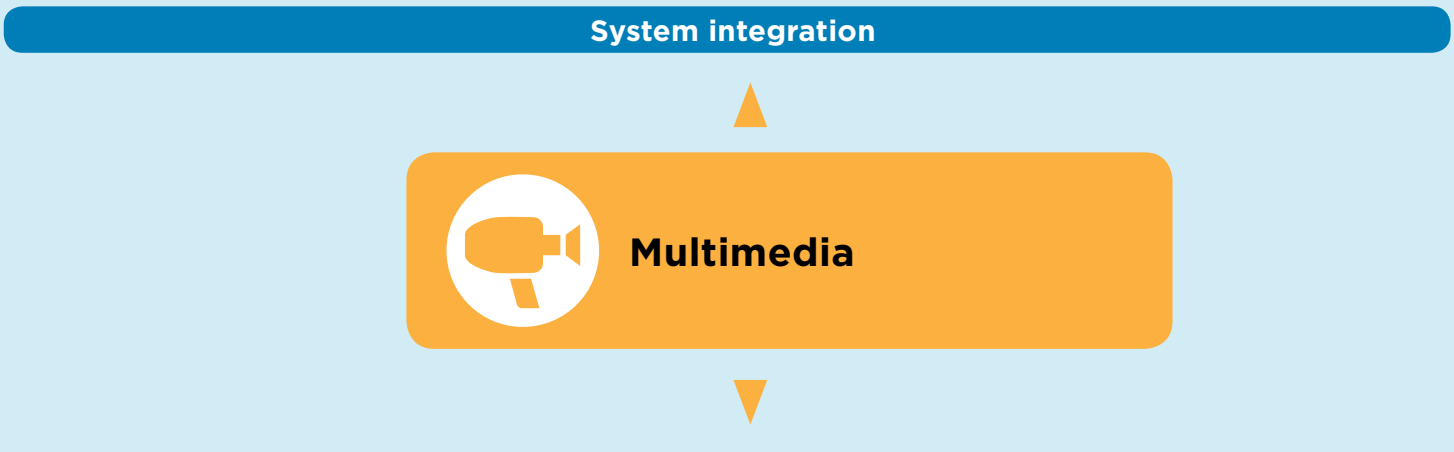
2. Sharing

The results of the developed product can be viewed using specific clients or via standardised protocols.

Standards

WebM/VP9 is the standard for embedding videos in HTML5 via the web.
H264/H265 is the standard for saving and sharing 4K videos. IMS OpenVideo allows videos to be saved in a chosen format and reused in a LMS. IMS LTI allows an external tool to be presented within a LMS.

Overview of standards and dataflow of Multimedia



Direction	Out	Out	Out	Out	In
Component	Organisation of learning Developing, managing and sharing learning materials	Organisation of learning Developing, managing and sharing learning materials	Organisation of learning Developing, managing and sharing learning materials	Organisation of learning Developing, managing and sharing learning materials	AAI
Standard	**MPEG 7**	**OpenGL**	**WebM** **H264/H265** **VP9** **IMS OpenVideo**	**IMS LTI**	**IMS LTI**
Data	• Metadata of videos	• 2D and 3D graphics and animations	• Video	• Learning activity • Learning materials	• Participant • Context

COMPONENT
FREELY AVAILABLE APPLICATIONS

Description

For some time now, students and lecturers have not limited themselves to using their institution's applications and systems. They choose their own favourite software and apps. Sometimes they even develop these themselves. In order to be able to personalise the digital learning environment, the institution must allow the integration of such tools. This is not feasible in all cases. Often, institutions specify per application whether integration is required or not.

The 'Freely available applications' component makes use of the following business objects. The component is responsible for the business objects indicated in **bold and blue**.

Business objects	Confidentiality	Integrity	Availability
Participant	H	H	M
Context*	L	M	M
Learning activity	L	H	M
Learning activity events*	L	M	L
CIA score	L	M	M
(regarded as learning material)			

* = Not in HORA H = High M = Medium L = Low P = Public

Position in the Flexible and Personal Learning Environment (FPLE)

Freely available applications belong, by definition, in the countryside, outside of the institution's sphere of influence. Of course, the institution can opt to include this component in education. Standards such as IMS LTI make this possible.

Functional description

This component does not have any fixed functionalities. This is because the applications are not defined. In order to integrate applications into the digital learning environment, however, they must be able to exchange data in line with certain standards. Furthermore, it is important to ensure that as many as possible of the activities students carry out in free applications can be recorded in learning analytics. This gives the institution insight into the use of free applications by a particular student.

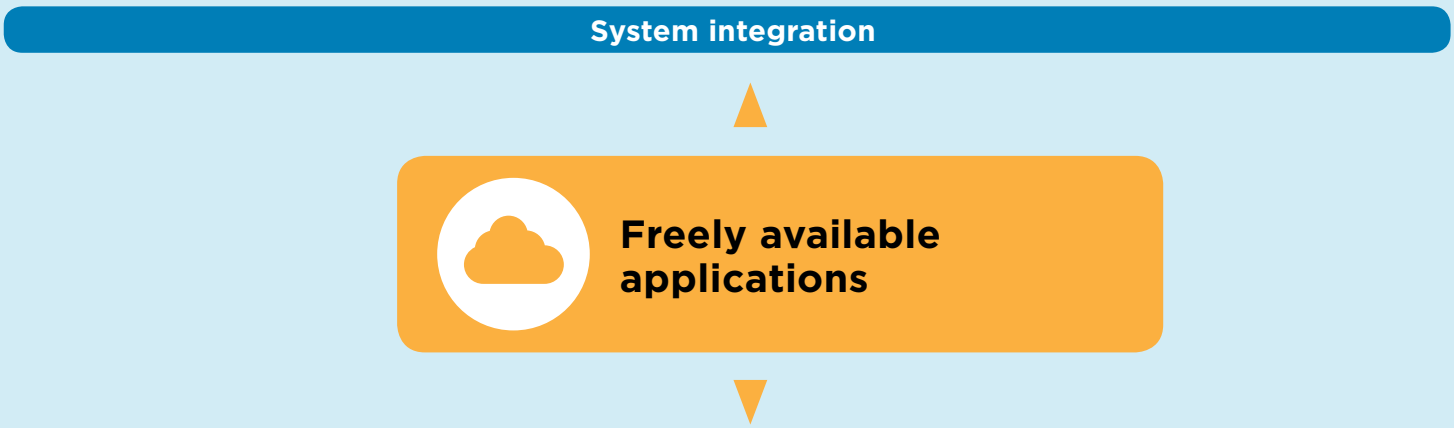
Authentication is also relevant here. An external tool can, for example, present a playback environment within the learning environment. This primarily occurs with tools run by another institution or a company that is connected to SURFconext.

In addition to enabling the use of external tools, it is also necessary to make these tools retrievable and exchangeable. To this end, IMS is currently developing IMS CASA (Community App Sharing Architecture).

Standards

IMS LTI allows an external tool to be presented within a LMS. IMS CASA makes applications (primarily those communicating with LTI) locatable and interchangeable. IMS Caliper and xAPI allow a student's learning activities to be described and communicated. This also means it is possible to document these activities in learning analytics.

Overview of standards and dataflow of Freely available applications



Data integration

Direction	In	Out	Out
Component	AAI	Organisation of learning	Learning analytics
Standard	IMS LTI	IMS LTI	xAPI IMS CALIPER
Data	• Participant • Context	• Learning activity	• Learning activity events

3. INTEGRATION AND INTERCONNECTION OF THE COMPONENTS AND STANDARDS

In the previous section, we described the data that is exchanged by each component and the most suitable standard for each particular type of data. In this section we address the connections and data exchange between the components.

INTEGRATION STANDARDS

Standards may result from legal requirements, technical guidelines or harmonisation within a sector. Standards often aim to:

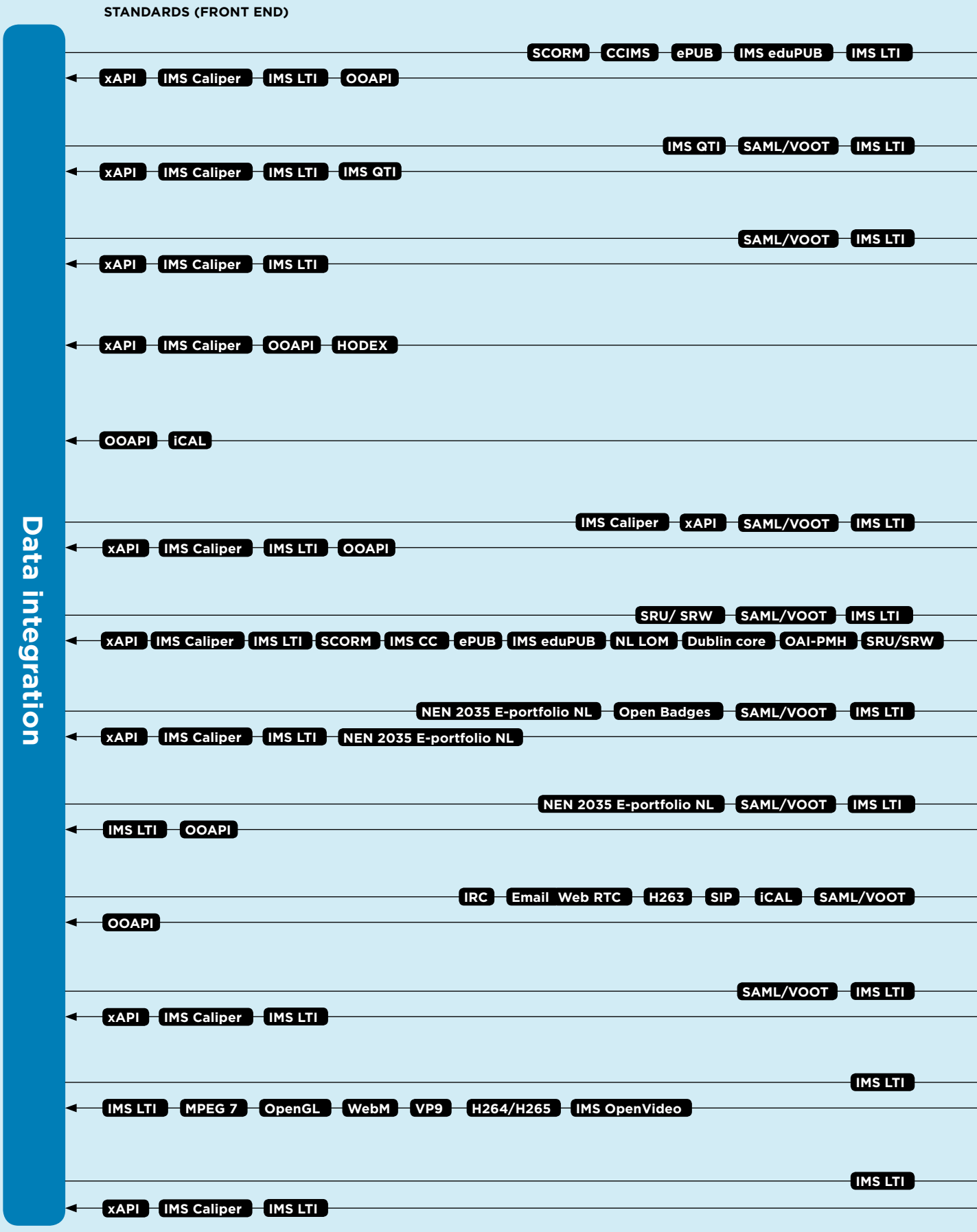
- make communication efficient;
- make information accessible; and
- reduce supplier-dependence by facilitating the entry of new implementation partners.

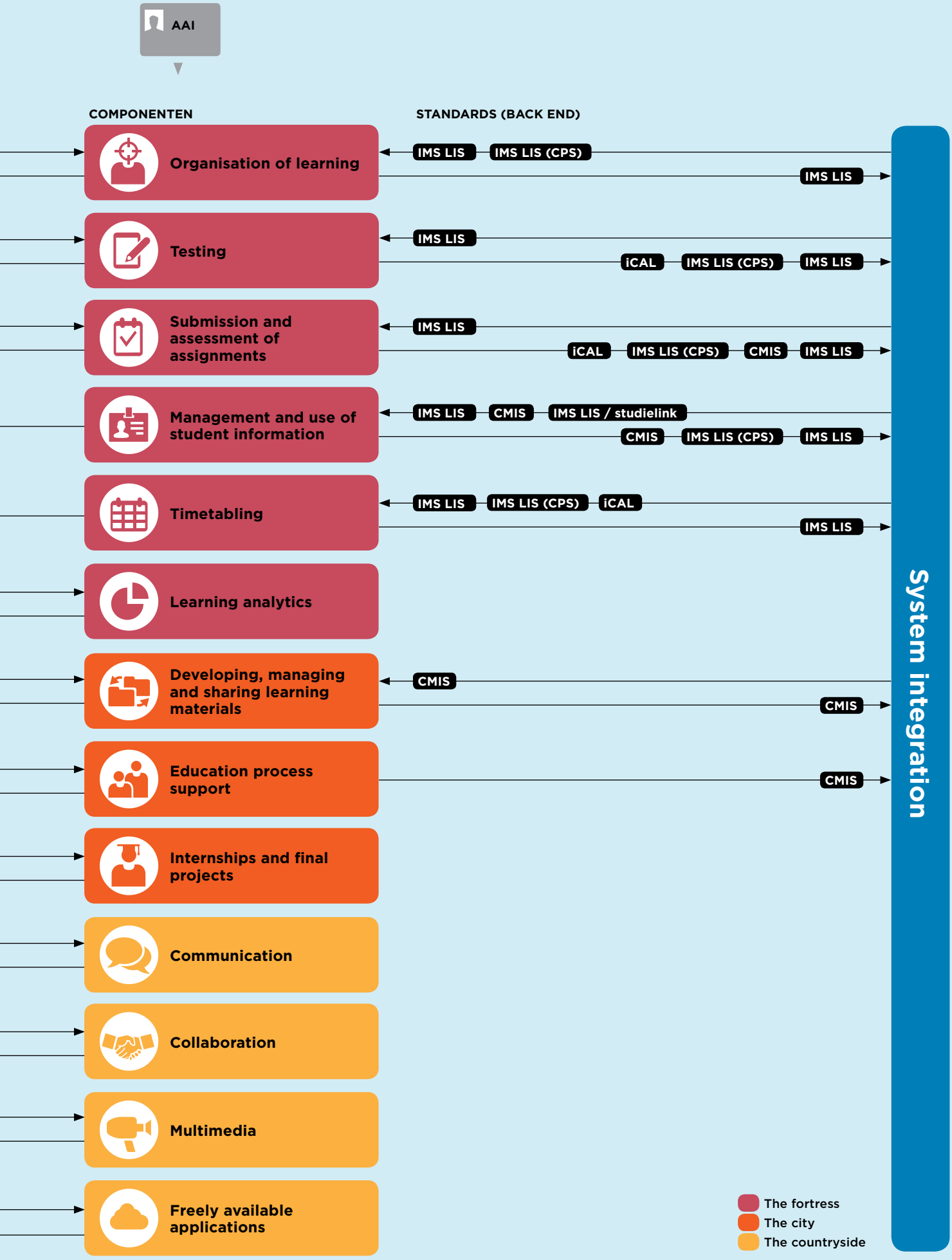
The use of standards ensures that the links between the various components are uniform. The standardisation of data exchange means that components can be used flexibly and are interchangeable. This gives institutions more freedom to select different components and suppliers. Standards also improve the 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. This results in a truly Flexible and Personal Learning Environment (FPLE).

The figure at the following pages provides an overview of the standards that are used for exchange between the components.

INTEGRATION STANDARDS

The most relevant standards per component




AAI
COMPONENTEN
STANDARDS (BACK END)
Organisation of learning
IMS LIS
IMS LIS (CPS)
IMS LIS
Testing
IMS LIS
iCAL
IMS LIS (CPS)
IMS LIS
Submission and assessment of assignments
IMS LIS
iCAL
IMS LIS (CPS)
CMIS
IMS LIS
Management and use of student information
IMS LIS
CMIS
IMS LIS / studielink
CMIS
IMS LIS (CPS)
IMS LIS
Timetabling
IMS LIS
IMS LIS (CPS)
iCAL
IMS LIS
Learning analytics
Developing, managing and sharing learning materials
CMIS
CMIS
Education process support
CMIS
Internships and final projects
Communication
Collaboration
Multimedia
Freely available applications
System integration
The fortress
The city
The countryside

When determining the components of the FPLE, it became apparent that many of the components use the same kinds of data. This is true of participant, group and curriculum data, for example. However, this also includes data on launching a component, the context of a user and information about user activity for the purpose of adapting learning analytics. Below is a list of the most relevant standards for the FPLE. We also describe the challenges related to each standard.

Relevant standards allowing integration between the components of the Flexible and Personal Learning Environment (FPLE)

Name of the standard	Available versions	Challenges and results for this standard
IMS[16] LTI	1.0 ; 1.1 ; 1.1.1 ; 1.2 ; 2.0 ; Outcomes services 1.0	LTI is a relatively new specification, but has quickly become very popular. LTI has achieved a high level of adoption for the versions between 1 and 1.2. Currently there has been only very limited adoption of version 2 and upwards. For a practical example, see: https://www.canvaslms.com/downloads/Openess-Infographic-2016.pdf. A recent LTI development is that LTI has become a framework for exchanging information via an LTI bridge on the basis of IMS specifications.
IMS Caliper	1	This is a very recent development. A number of major LMS providers are currently working on implementation. This specification also features in broader LTI developments.
TinCan xAPI		This standard is popular, and the specification has been released under an Apache 2 license. It is a specification, and not a code. Currently, it is primarily used by small software builders. Large e-learning providers seem to be somewhat reluctant to endorse this standard. The question is how the market will develop now Caliper has been released by IMS. In addition, xAPI still has some opportunities available in the more traditional area of SCORM.
OOAPI[17]		This specification in-the-making is currently limited to the SURF community. This means very limited adoption of this standard. However, it does have a lot of potential as it responds to a specific demand from its own field.
IMS LIS (Enterprise) OneRoster	LIS 1 ; 2.0 ; 2.0.1 ; OneRoster 1	A difficult specification. In actual fact, it is solely supported by major suppliers: Oracle/Peoplesoft, Blackboard, Canvas and other LMSs. With the introduction of simplification on the basis of OneRoster, there is expected to be greater adoption among the smaller organisations.
SAML		A de-facto standard for exchanging authentication and authorisation data between domains.
VOOT		This standard is primarily used in the international NREN (National Research and Education Network) world. As a result, adoption is limited.

16. *For adoption and certification of the IMS standards, see: https://www.imsglobal.org/conformance-list*
17. *http://openonderwijsapi.nl/* (in Dutch)

Relevant standards for exchange of content

Name of the standard	Available versions	Challenges and results for this standard
IMS QTI	1.2 ; 1.2 Lite; 2.0 ; 2.1 ; 2.2	QTI has a long history, but only limited adoption. QTI is primarily used in scenarios where questions (items) are developed and/or managed in one system and provided via another system. The adoption process has encountered some difficulties. The main reason for this is the complexity of the standard.
ADL SCORM	1.2 ; 1.3 ; 2004	Commonly used, a traditionally strong player. Most LMSs and e-learning content systems support a form of SCORM.
IMS CC	1.0 ; 1.1 ; .1.2 ; 1.3	Reasonable support by common LMS systems.
ePUB	1 ; 2 ; 3 ; 3.0.1	ePUB is usable in a broad range of contexts, and is a general standard (http://idpf.org). In connection with IMS, there is also EduPUB, an extension of Epub3 (http://www.idpf.org/epub/profiles/edu/spec/#h.9mbgl5v4t4qc).
CMIS	1.0 ; 1.1	CMIS is also commonly used outside of higher education in the world of business.

Interesting standards to keep an eye on in future

Name of the standard	Available versions	Challenges and results for this standard
Open Badges		Badges in general appear to be growing more popular for demonstrating experience and (part) certification. Open Badges is based on the Mozilla initiative and is applicable in a wide range of contexts, but there is not yet much experience with or knowledge of this standard in Dutch higher education institutions.
IMS CASA	whitepaper	This specification has a lot of potential when it comes to managing and developing a component ecology for e-learning solutions. It can be used to find relevant components from the countryside or content for the FPLE (https://www.imsglobal.org/activity/community-app-sharing-architecture-casa).

In the lists above, the IMS specifications hold a particularly important position. This set of standards covers the entire spectrum of activities associated with Organisation of learning. These specifications are aligned with and complement one another. The mutual relationships between the specifications can be found on the IMS website[18].

18. *https://www.imsglobal.org/initiative/enabling-better-digital-credentialing*

All standards in the tables above are open standards. Open standards contribute to interoperability and supplier-independence. Open standards are not software-specific, and can be integrated into an ICT system by any supplier.

The Dutch Standardisation Forum applies the following criteria to open standards:
- management by a not-for-profit organisation
- open decision-making procedure
- waiver of intellectual property rights
- publication of the standard
- specification document available for free or in return for a nominal contribution
- sustainable financing
- no restrictions on re-use.

CHALLENGES

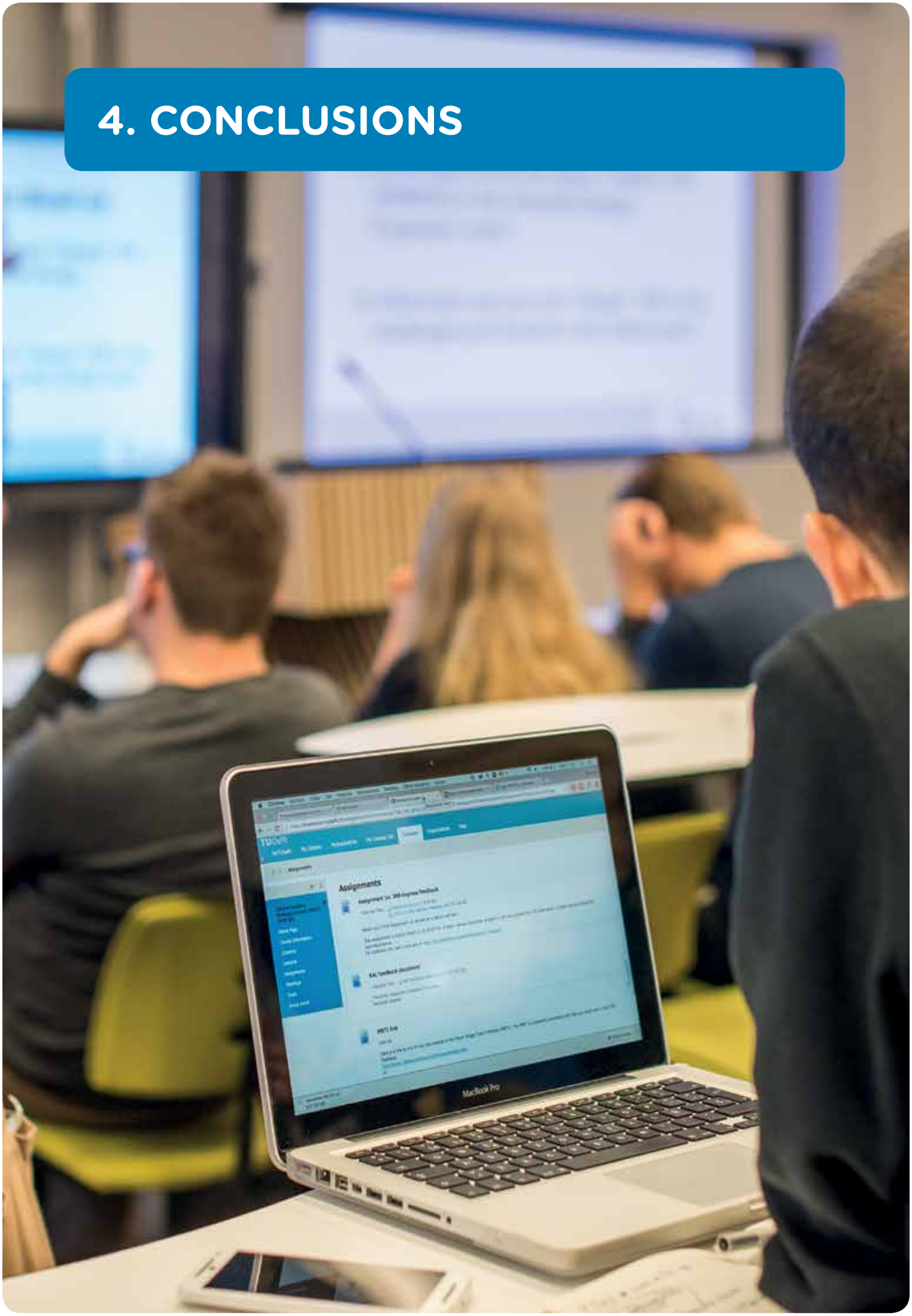
In order to make effective use of standards, we also need to bear in mind their maturity and (market) adoption. Because if a standard is used rarely or not at all, there is little chance that an institution will be able to find enough parties to exchange data with on the basis of this standard.

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. These aspects must also be taken into account in standardisation.

There is awareness of many of the aforementioned 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. SURF's StandardWiki[19] will provide information about the various cases and the relevant standards.

19. *www.wikixl.nl/wiki/surfstandaarden* (in Dutch)

4. CONCLUSIONS



In the previous sections the different components and their connections have been addressed. In this final section we will demonstrate how to construct a functional model for a flexible and personal learning environment based on this information.

The objective of this paper was to investigate:
1. what data and functionalities the components of a digital learning environment are composed of;
2. the way in which the components are interlinked;
3. the standards which can be used for the exchange of data between components.

In Section 2, we listed the data and functionalities for each component in order to clarify which data and functionalities the components of a digital learning environment are comprised of. On the basis of the basic principles set on page 8, we also mapped the exchange of data between components. The result of this can be found in Section 3.

FUNCTIONAL MODEL

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. This underlines the mutual responsibility of components for one another.

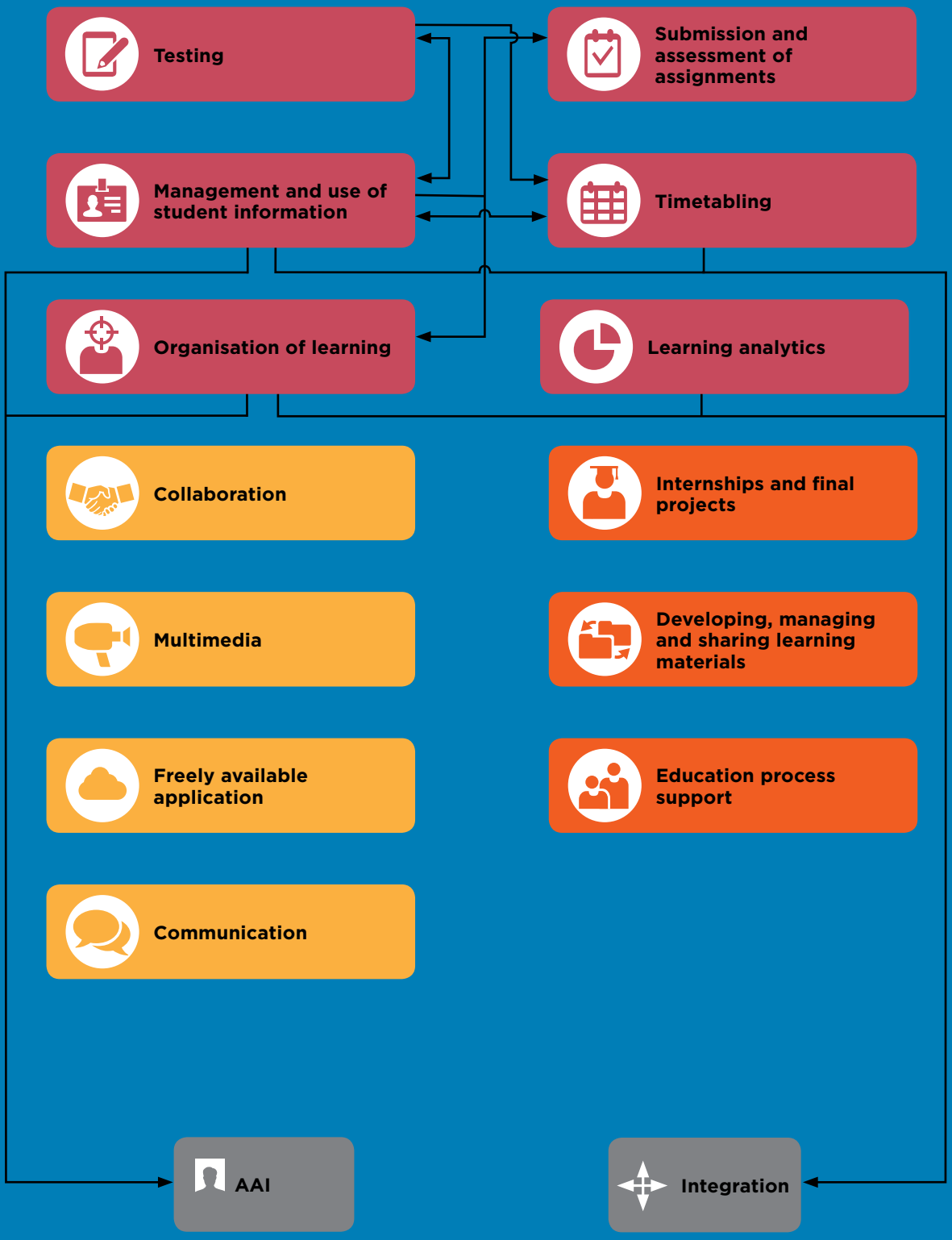
This interlinkage between te components is clearly illustrated in the figures on the following pages.

The first figure ‘system integration’ depicts the interconnections between the components. 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 AAI and integration.

The figure ‘data integration’ depicts the four 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 OOAPI. The further shaping of organisation of learning is realized through IMS 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 by done by means of SAML/VOOT.

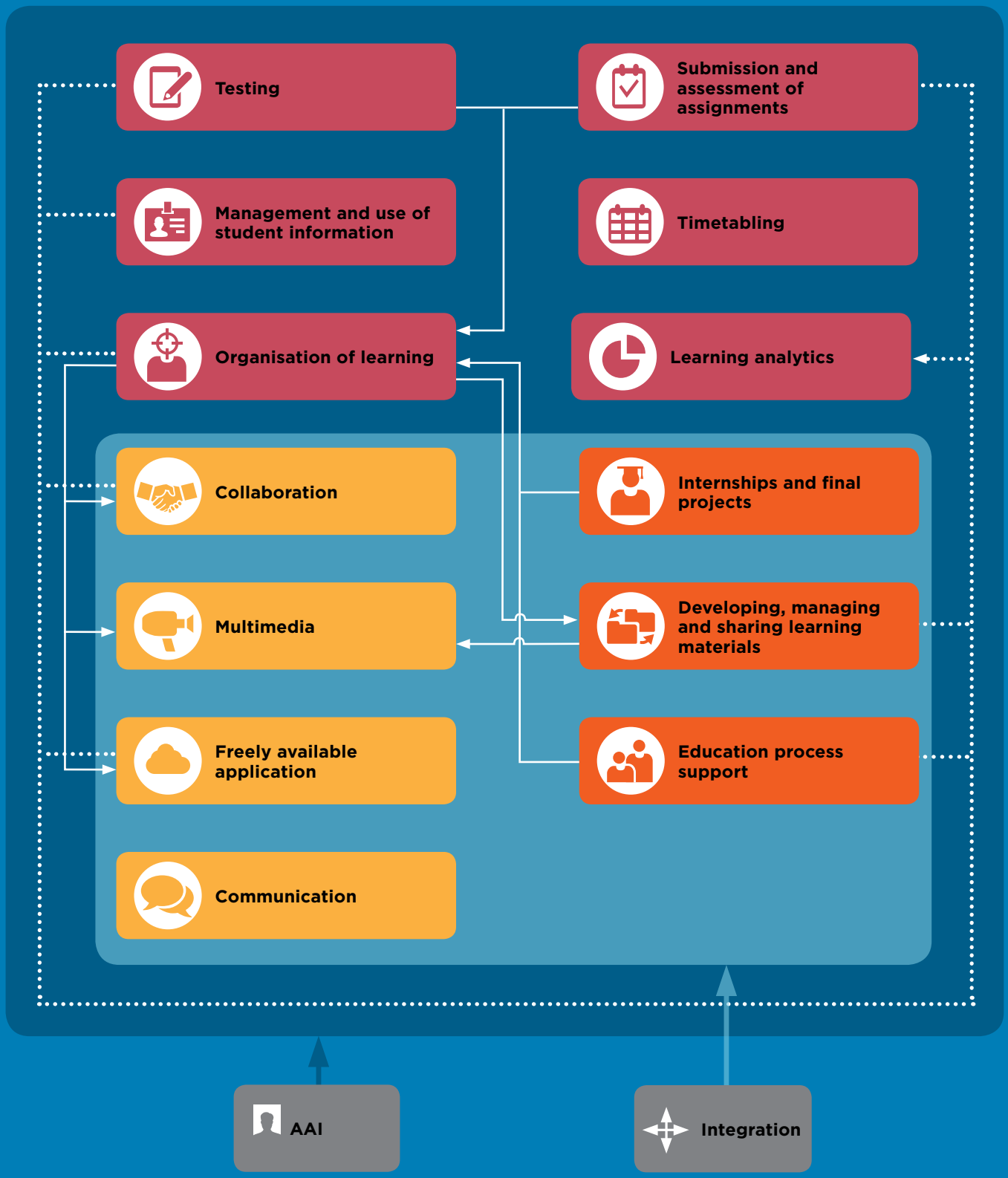
SYSTEM INTEGRATION



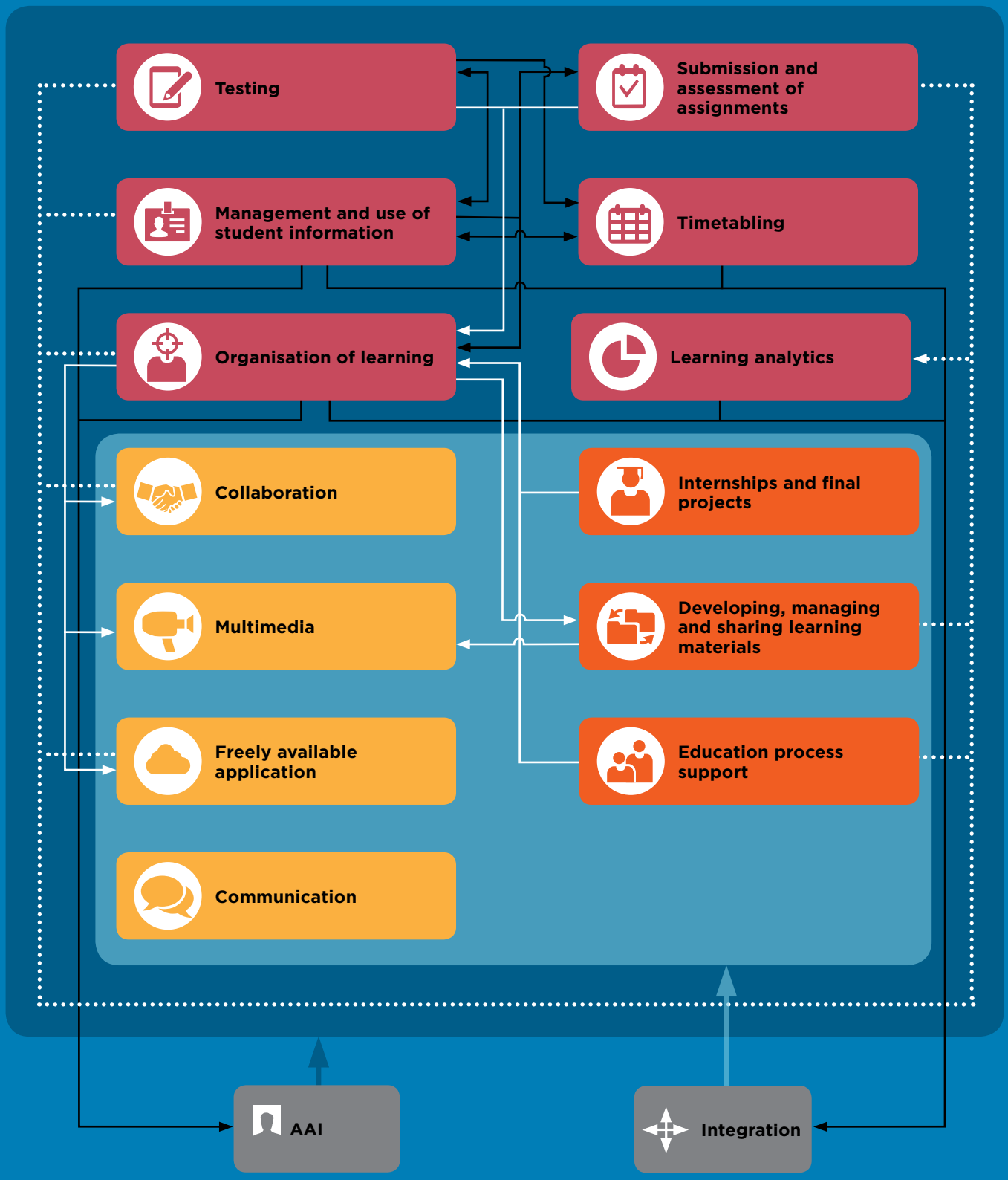
Legend

→ LIS

DATA INTEGRATION



FUNCTIONAL MODEL



Legend

LIS → LTI → SAML/VOOT

XAPI → OOAPI

Functional model

The figure on the pervious page provides an overall overview of the interconnection between the components as well as the most relevant standards.

If we zoom in further and look at how the lines go, we arrive at the following functional model:

Reuse of personal data
Of the educational support components, 'Management and use of student information' is key. This component provides data about students and courses, data which is reused by a large number of components. **IMS LIS/OneRoster** is the most commonly used standard for this purpose.

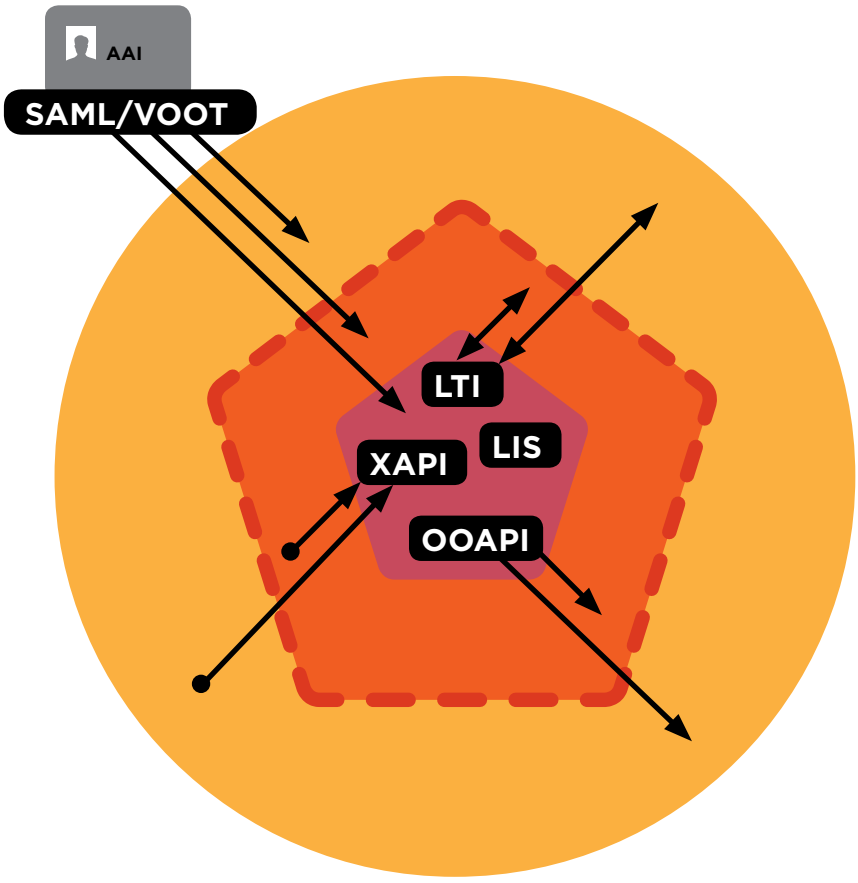
Tailored delivery of content to students and combining learning materials that are distributed across the various sources
The component 'Organisation of learning' plays a pivotal role, as it is the launch pad for the learning process in the 'Developing, managing and sharing learning materials' component. We favour **LTI** for this purpose. This component also acts as a portal, from which components such as 'Communication', 'Collaboration' and 'Freely available applications' are launched.

Overview for students' own activities
The 'Learning analytics' component is where all data about learning activities from the other components is aggregated. Learning activity events are gathered using the **xAPI** standard.

Personalisation and provisioning of group information to components
As for integration with the AAI infrastructure, SAML/VOOT allows all components to be personalised and assigned to groups that can be used in the learning environment.

Re-use of student and course information
Fortress information can be used in the city and the countryside by using the **OOAPI** interface. This would allow freely available applications to gain access to this data.

Main standards



THE RESULT: COMPLETION OF THE TRILOGY

In the document entitled 'A flexible and personal learning environment, from single components to an integrated digital environment; a survey[20]', we set out the components that a Flexible and Personal Learning Environment should be comprised of.

This document and the diagrams found in the conclusions illustrate the potential links between the components. The functional model is a suggestion towards realisation of the learning environment. It is dependent on the specific characteristics of the institution and the educational process applied.

Logically, the next step would be to conduct practical testing. This should involve investigation of the following questions:

- To what extent is the model technically functional?
- To what extent does the model tally with the educational model of the institution? Different processes apply to different methods such as blended learning, flipped classrooms, adaptive learning or collaborative learning.
- What should be done in terms of visual integration? This functional model focuses on data and system integration. Visual integration was not addressed because this requires a visual skin to be applied to applications. As such, it is only possible to start looking at visual integration once implementation has begun. Possible components of this include portals, apps and accessibility.

This results in a trilogy. On the basis of the initial document, we have created this functional model. This will then result in a technical workbook[21], which discusses how the model can be implemented. In the future, experiences of institutions will be added to this workbook.

20. *https://www.surf.nl/binaries/content/assets/surf/en/knowledgebase/2016/memorandum-learning-environment_uk_web.pdf*
21. *https://wiki.surfnet.nl/display/TWFEPL/Technisch+Werkboek+Flexibele+en+Persoonlijke+Leeromgeving+Home* (in Dutch)

LIST OF TERMS

Authentication and authorisation infrastructure
Gives the user access to the components in a uniform manner (authentication), and ensures that the role of the user is known within each of the components (authorisation).

Business function
An element in the business function model that indicates where logical units and boundaries are found in the organisation, processes and provision of information.

Business function model
A list of functions that must be fulfilled within an institution. It describes what an organisation does without going into how it does it. The model clusters activities into logical units requiring similar knowledge and competences.

Business object
A set of data that is relevant to the execution of business processes.

Components
A functionality that allows a specific educational task to be performed properly. They provide functions such as communication, collaboration, testing, timetabling and the Submission and assessment of assignments. These are the foundations upon which a digital learning environment is built.

Data integration
Exchange of data in order to make a particular functionality possible. Data integration often takes place via public networks.

System integration
Exchange of data in the back office, often via protected networks.

Learning analytics reporting
Overview of the aggregated information about one student.

Learning activity event
Data about an activity performed at a specific moment in time by an individual educational participant.

Learning groups
Groups that are formed in connection with a project or collaborative learning arrangement. Learning groups are often dynamic, and vary from assignment to assignment.

Class groups
Groups of students following a particular learning unit. Participants in such a group have enrolled in this unit of study, and have been included in timetabling.

Unit of study result
The overall result for a unit of study, based on the underlying test results. (http://www.wikixl.nl/wiki/hora/index.php/Onderwijseenheidresultaat, in Dutch)

LIST OF ABBREVIATIONS

Systems:

LMS	Learning Management System
LRS	Learning Record Store
SIS	Student Information System

Standards:

API	Application Programming Interface
CMIS	Content Management Interoperability Services
CPS	Course Planning and Scheduling
HODEX	Higher Education Data Exchange
IMS	The Instructional Management System project
IMS CASA	Community App Sharing Architecture
IMS CC	Common Cartridge
IMS LIS	Learning Information Services
IMS LTI	Learning Tools Interoperability
IMS QTI	IMS Question and Test Interoperability
IRC	Internet Relay Chat
LDAP	Lightweight Directory Access Protocol
LOM	Learning Object Metadata
OAI-PMH	Open Archives Initiative – Protocol for Metadata Harvesting
OOAPI	Open Education API
Open GL	Open Graphics Library
SAML	Security Assertion Markup Language
SCORM	Sharable Content Object Reference Model
SRU/SRW	Search/Retrieval via URL / Search/Retrieve Webservice
VOOT	Virtual Organization Orthogonal Technology
xAPI	Experience API

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