Introducing Competences into LTI-Connections between Learning Management Systems and Gaming Platforms

Integrating the RAGE Analytics Environment into Moodle Courses

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***Abstract*—E-learning standards like *Learning Tools Interoperability (LTI)* can support software developers and course authors at realizing innovative learning scenarios in distributed architectures. Standardized interaction processes enable learning platforms like *Learning Management System (LMS)* to delegate functionality to LTI-compatible external tools in a flexible way. An LTI-connection between an LMS and a gaming platform offers possibilities like embedding a game or game asset into an online course and sending player-specific data tracked during gameplay back to the LMS. This allows for a new, more objective, and data-driven evaluation of students' individual learning performances, either for traditional grading processes or for alternative methods like *Qualifications Based Learning (QBL)* [3-5]. This paper outlines an approach which uses standardized interaction technologies for combining game-based and competence-based learning concepts.**

Keywords—Competence Based Learning; Game Based Learning; Learning Tools Interoperability; Distributed Online Courses; Moodle; Moodle Extensions; Competency Based Education

I. INTRODUCTION AND MOTIVATION

IT-infrastructures at Higher Educational Institutions (HEIs) nowadays are required to offer the best possible conditions for seamlessly integrating innovative tools and technologies into online learning programs. A key component for organizing and executing courses is the ***Learning Management System (LMS)*** - in many cases an open-source software based on a plugin-architecture which offers an ***Application Programming Interface (API)*** for developing extensions without modifying the core code. However, this flexible way to introduce additional functionality is not intended for the replacement of well-established e-learning tools with LMS add-ons of lower quality. In many cases, a distributed solution for transparently embedding external tools or resources into LMS-sided online courses is a better choice. The ***Learning Tools Interoperability (LTI)*** standard [1] has been designed for that purpose and provides mechanisms for authorization, authentication, tool launch, and data exchange. LTI is supported by many modern LMSs; for example, ***Moodle*** [2] offers a generic plugin for specifying LTI-connections.

LTI allows for the implementation of innovative learning scenarios within online-courses because besides, e.g., new media types, miscellaneous software systems can be easily integrated into the learning process. This includes games and gaming platforms, so LTI can be used to introduce game-based learning approaches into learning environments that originally have not been specifically designed for this kind of education. An LTI-connection between an access-protected game or gaming platform and the LMS would enable an LMS-course to embed a game or game asset as a standard course resource which can be opened from within the course. After the connection is configured, the fact that the embedded object is hosted by an external system is hidden both from producers (teachers, trainers, etc.) and from consumers (students). However, during such an applied gameplay, user-specific data about progress, status, and history have to be collected by the game or gaming platform. Especially in the context of educational games, this tracking functionality is optimized for evaluating criteria like a player's learning performance and capabilities, so on LMS-side these data can also be applied, e.g., to support some grading or certification procedures. Alternatives to traditional grading processes are competence-based approaches like the ***Qualifications Based Learning (QBL)*** concept described in [3-5][1]. In this case, the performance data tracked during gameplay would be used for assigning competences and updating personal competence profiles. The ***RAGE Analytics Environment (RAE)*** [6,10] is a gaming technology platform which provides appropriate

[1] Our former publications use the term Competence Based Learning (CBL).

tracking functionality and also supports LTI; at the moment, the developers are working on an improved solution for data exchange with LMSs. The RAE is a further development of the approaches and software systems described in [7-9].

In the remainder of this paper, we describe a way to combine game-based and competence-based learning concepts by connecting an LMS with a gaming platform and exchanging competence-relevant information. At the moment, our solution remains a design and specification on a conceptual level. A prototypical implementation based on the RAE technology and the Moodle LMS is scheduled for the near future.

II. Problem Statement and Research Objectives

In a conventional learning platform like a ***Learning Management System (LMS)***, game-based learning concepts usually play a minor role because it is complex to integrate games into the learning flow. Nevertheless, to some extend it is possible to implement such approaches with maintainable effort when those software systems already support interaction standards like ***Learning Tools Interoperability (LTI)*** [1] and content standards like SCORM [11]. LTI plugins enable course authors to embed resources provided by external software systems. SCORM plugins can be used for deploying and executing uploaded games and accessing basic game-specific data (e.g. scores). A solution that depends on uploaded files and a specific runtime engine cannot be regarded as a seamless integration of external resources within a distributed architecture [3-5], so SCORM cannot be the method of choice. Embedding an externally (outside of the LMS) hosted game or game asset requires an LTI-based solution.

Nowadays, common learning platforms at least support basic LTI-functionality like authentication, tool launch inside the LMS (e.g. in an iframe), and receiving simple scores to be stored in the students' gradebooks. Regarding the integration of games and game assets, LTI's limited possibilities for data transfer between embedded tools and the LMS are a ***problem***, because a wide variety of user-specific data tracked during gameplay sessions has to be evaluated on LMS-side. Therefore, we depend on a game technology that is able to transfer the required data. This already has been subject of former research projects [6-10]; in [7], del Blanco et al. compared a SCORM- and an LTI-based approach. As LTI's outcomes functionality was limited to a simple score at this time, the authors preferred SCORM. Since then, additional features like integration of in-house developed web services and writing access to data structures on LMS-side have been introduced to the LTI standard. This offers new possibilities regarding data exchange, so the reasons for discarding the LTI-based solution actually have to be reviewed. Nowadays, LTI-based connections offering extensive interaction mechanisms between LMS and gaming platform seem to be realistic and feasible.

As described in [6-10], a configurable tracking functionality is a key element for supporting gaming platforms at collecting user-specific information about gameplay sessions in a targeted way. In the context of game-based learning, these data are used for evaluating a user's individual learning performance; our QBL-concept (Qualifications Based Learning) adopts this approach for assigning competences and other qualifications. The consequences for and specific requirements on user tracking have to be ***researched*** and an adequate solution has to be designed and implemented. This includes an LTI-compliant transfer of user-specific, competence-based gameplay data from the gaming platform back to the LMS. Another ***research objective*** is concerned with the evaluation of these data on LMS-side. Solutions have to be compatible with the competence model defined by Then et al. [5] which is part of our QBL-concept.

III. State of the Art

In the previous sections, some research projects and software systems related with our approach have already been mentioned. In the following, some of them are described in more detail.

A. Qualifications Based Learning

Along with the Europe-wide university-reform called ***Bologna Process (BP)*** [12], the European countries made some agreements concerning the comparability and quality of higher-education study programs, modules, and courses. As a consequence, each course has to be provided with academic credit points according to the ***European Credit Transfer System (ECTS)*** [13]. Furthermore, the conveyed qualifications have to be stated and categorized in a determined way by assigning so-called ***Competences***. A binding accreditation process which every course provided by a European university or college has to pass ensures compliance of these criteria. The fact that every course has to provide a so-called ***Learning Goal (LG)*** description containing a summary of all conveyed competences, on first sight seems to enable students to integrate a greater flexibility into their curricula. Unfortunately, that expectation has not been fulfilled; the comparability of learning content has not increased in the degree originally aimed by the BP, because competences are usually described in form of free text and every faculty in every university uses its own formulations. This leaves too much space for interpretation and misunderstandings.

As a consequence, standardized qualifications catalogues have been developed; of special interest for the IT-sector and computer science in general are the ***European e-Competence Framework (e-CF)*** [14,15] and the underlying ***European Qualifications Framework (EQF)*** [16,17]. To increase the comparability of learning content based on competences, the QBL-approach described by Then et al. [3-5] includes a domain class model for representing standardized qualifications (like competences, skills, and knowledge) and frameworks like the e-CF. Furthermore, this so-called ***Qualifications Based Learning Model (QBLM)*** [5] is designed to equip competences with ***Proficiency Levels (PL)***. Competences and their PLs can be bundled to ***Competence Profiles (CP)*** which can be used as LGs in the meaning of the BP. In other words: the QBLM provides a way for modeling qualifications (e.g. competences) and assigning them to learning content. Our former publications [3-5] use the term ***Competence Based Learning (CBL)*** instead of QBL. As the approach is designed to support qualifications frameworks like the EQF and the e-CF, which divide qualifications into

competences, skills and knowledge, the terms QBL and QBLM are more accurate.

Learning objects like units, activities, and knowledge resources can be represented with the ***Personal Competence Domain Model (PCDM)*** described by Vogten et al. [18]. It has been developed in the context of the ***TENCompetence Project (TCP)*** [19,20]. A special characteristic of the PCDM is its competence model, which later has been the extended by the QBLM. Regarding learning objects, goals, plans, and assessments, the PCDM is oriented towards ***IMS Learning Design (IMS LD)*** [21], a common specification developed at the ***Open University of the Netherlands (OUNL)***.

The QBL-concept assumes that competence data have to be accessed by diverse software components of an educational institution's IT-infrastructure. Within this distributed architecture, the LMS is regarded as a central element for course organization and execution, so it has to support QBL and the QBLM in any case; an extension for the Moodle LMS is presented by Then et al. [5]. As Moodle already provides basic support for competences (since version v3.1), our QBL-plugin is designed as an extension for this functionality and therefore includes a mapping between the QBLM and Moodle's competence structures. The QBL-plugin for Moodle is a work in progress and not yet fully implemented.

B. Learning Tools Interoperability

LTI is a standard for tool interoperability that can be used for integrating externally hosted resources like forums, chat rooms, wikis, assignment tools, or games and gaming assets into learning platforms like LMS [1]. The embedding system, in our case the LMS, acts as a so-called ***Tool Consumer***. The platform which provides the external resource is called a ***Tool Provider***. The basic features of LTI are:

- ***Single Sign On (SSO)*** on the basis of a standardized authorization/authentication procedure;
- Launching external resources from within LMS-sided courses, units or activities;
- Returning a basic outcome like a score back to the LMS.

To secure access, LTI uses the standard ***OAuth*** (for more details about OAuth and security issues see Hammer-Lahav [22,23]). In brief: consumer and provider exchange a so-called ***Consumer Key*** and a ***Shared Secret***. Successful validation of a request means that the sender is identified as an authorized resource from the LMS, for example a course or activity. In case of success, the next step is to verify users and their roles - do they have the permission for the requested action in the context of the requested resource? If approved, users will be logged in, a user session is created, and the provider tool is launched inside of the requesting course (i.e. in an iframe or as a separate window).

With LTI-version v2.0 [1], the concept of configurable contracts between individual consumer- and provider-side resources has been introduced. Such a contract, called a ***Tool Proxy***, among other things can be used for offering specific services on consumer-side. Regarding an integration-solution for a specific LMS, this offers interesting perspectives: providers can, e.g., be authorized to store data on LMS-side, access courses and check enrolments. However, such solutions somehow contradict the idea of standardization because they are limited to a single combination of software systems.

C. Moodle as an LTI-Consumer

The plugin ***External Tool*** [24], also referred to as ***LTI-Consumer Plugin***, enables Moodle users having admin- or teacher privileges to integrate protected resources from external applications into Moodle courses via LTI. The user does not need to have any deeper knowledge about LTI, but a basic understanding is advantageous. Within a Moodle course, an LTI connection is established by creating an activity-instance of type External Tool, which contains authorization parameters and essential information like the URI of the target resource - for example an assignment or a game. From a student's perspective, the LTI-connection works like a typical LMS-activity: a click on the corresponding link opens the resource.

The basic functionality for our approach (authorization/ authentication, tool launch, and return of outcomes) is already implemented by the LTI-Consumer Plugin. Furthermore, the LMS Moodle is open-source, so it offers perfect conditions for using it as a starting point for our prototypical implementations aiming at merging competence-based and game-based learning approaches by using the LTI technology. Since Moodle-version v3.2, released in December 2016, the LTI-Consumer Plugin supports LTI v2.0.

Creating an LTI connection in Moodle is quite simple, as long as the targeted software system supports LTI; at [25], a list of certified tools is provided. Gaming platforms usually will not provide LTI support, unless they are designed to be used for game-based learning approaches and data exchange with learning platforms. An innovative approach for such concepts is the ***RAGE Analytics Environment*** (see III.A).

D. FUH-WebAssign as an LTI-Provider

At the University of Hagen (German: ***FernUniversität in Hagen, FUH***), several online tools have been developed during the last decades, which are individually tailored to the needs of faculty, staff, and students. Most of these initially used in-house software solutions are nowadays to some degree outdated and have already been replaced by now, but some of them are still in use today. For example, the assignment tool ***FUH-WebAssign (WA)*** [31] is widely accepted by faculty and staff because it supports some particular FUH-specific workflows. Many learning content producers worked with WA for years and spent a lot of time developing their assignment scenarios and teaching environments with it, so a mere replacement with Moodle's assignment tools has never been an option. As a consequence, WA has been kept as a legacy system and extended to support LTI; the concept has been presented by Then et al. [30] in 2015. The new capability to act as an LTI tool provider enables course authors to embed WA-content (assignments, quizzes, tests) into Moodle courses by using the LTI-Consumer Plugin. An example is displayed in Fig. 1 and a manual for authors and teachers is available, see [32].

In Moodle, a so-called gradebook is used for recording students' individual course performance. All grades for course activities have to be registered there, including the scores achieved in external e-learning tools embedded via LTI. For transferring the required data to Moodle, WA uses the standard LTI outcomes service which is limited to a simple score and supported by Moodle's LTI-Consumer Plugin. A more extensive feedback is not necessary. As WA is not designed to support competence-based approaches directly, competences can only be attested in relation with these outcomes. For automating this process, configurable transformation rules on Moodle-side would be helpful; a proof-of-concept implementation of this is scheduled for the near future. For example, Moodle's grading scale functionality can be extended in a way that enables authors and teachers to define dependencies between achieved scores and competences (QBLM-qualifications).

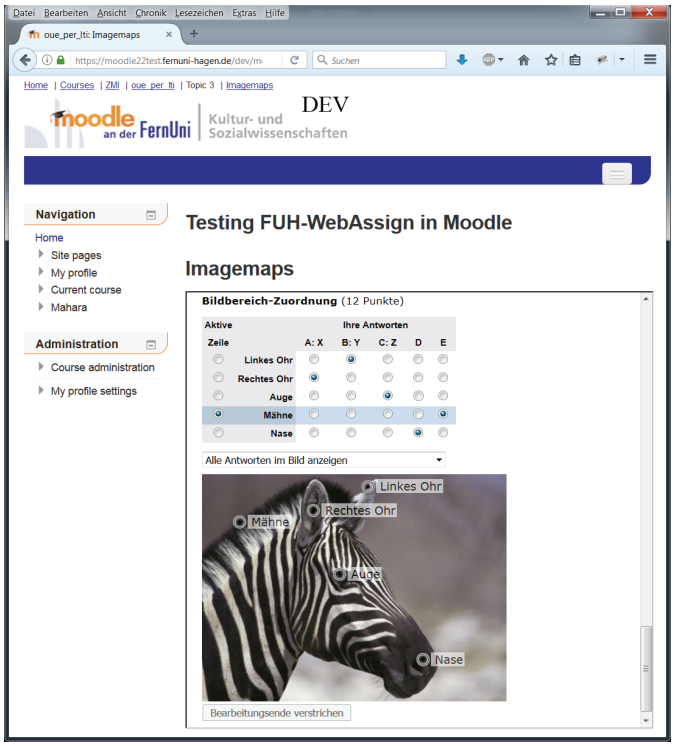

Fig. 1. Assignment from FUH-WebAssign, embedded into a Moodle-course.

E. *RAGE Analytics Environment*

The ***RAGE Project*** [26] aims at supporting the game industry at developing serious and educational games easier, faster, and more cost-efficiently. The main objective is to develop an eco-system of self-contained gaming assets (well-documented software components) that can easily be used and included by serious games.

The ***RAGE Analytics Environment (RAE)*** [6,10], a platform which collects, analyzes and displays learning analytics data from games, uses a flexible authentication and authorization module for enabling other RAGE server-side assets to access RAE-resources by using standard interaction technologies like LTI or the *Security Assertion Markup Language (SAML)* [27]. As RAE supports such standards, it is possible to embed RAE-assets into online courses provided by learning platforms like the Moodle LMS; for a description of Moodle's capabilities regarding LTI see section III.C. In terms of LTI, the RAE takes the role of the tool provider and manages the access to the analytics tools, which are intended to be embedded on LMS-side. Launching the actual game from within the LMS is not implemented by the RAE at the moment, but it is considered for future development.

The RAE has been developed at the ***Complutense University of Madrid, Department of Software Engineering and Artificial Intelligence***, and is based on former research and software projects concerning game-based learning (including the ***eAdventure*** game authoring platform). Del Blanco et al. [7] researched how to use e-learning standards to integrate games into LMS, in particular, they proposed three integration models. One of them uses LTI to facilitate the integration of a gaming platform and an LMS; another one uses SCORM. A concept for designing educational games with a view to LMS-integration and IMS LD is presented by Moreno-Ger et al. [8]. A prototypical implementation based on the gaming platform eAdventure is described by Burgos et al. [9].

With regard to our QBL-approach, the concept for tracking user-specific data during gameplay and exchanging them with the learning platform is of special interest. The RAE, more precisely the underlying concept for educational game design, assumes that user-tracking is already considered during game design. The tracked data then have to be returned to the LMS by using a suitable interaction mechanism. Currently, a feature for this purpose is under development: a mechanism will be provided, which allows the registration of an endpoint (webhook) that will send a notification when a new gameplay session is created and ready to process. This notification will include several ***Elasticsearch*** (a distributed, RESTful search and analytics engine [28]) indexes, which can be used to identify the data logged during gameplay, and the indexes belonging to evaluation data produced by the RAE analytics tools. This functionality can be used for continuous monitoring of a gameplay and establishing a data stream from RAE to the LMS, more precisely: to an LMS-extension for processing these data.

IV. Conceptual Design

Bidirectional communication between LMS and gaming platform can be implemented by using common e-learning standards like LTI [1] and SCORM [11]. On first sight, LTI seems to be the appropriate technology for integrating a game or game asset into an online course, because it assumes that the involved resources are hosted in separate systems. However, there are alternative solutions which, depending on type and extent of data exchange, might be a better choice. In [7], del Blanco et al. describe three models for integrating games into LMSs, one of them proposes the use of LTI, another one is based on SCORM. In 2013, when the paper was published, the LTI-specification has been limited to basic functionality like SSO and returning a simple score, thus the authors preferred the SCORM-based solution which allows larger scaled data exchange.

Since LTI-version v2.0 [1], which has been released in 2014, so-called ***Tool Proxies*** (***TPs***, see section III.B) are part of the LTI-specification. They can be interpreted as configurable contracts between consumer and provider, which can include URIs of consumer-sided web services. In our use case scenario, this would enable the gaming platform to send user-specific performance data back to the LMS. A disadvantage of this approach is its limitation to a single combination of software systems, which is a contradiction to the idea of standardization.

As mentioned at the end of section III.E, it is planned to extend the RAE with a mechanism that notifies the consumer about recently started gameplay sessions. The notification includes metadata which later can be used by the LMS for accessing RAE-sided information about a user's performance during gameplay. This approach might be combined with an LTI TP: a service for receiving and processing those notifications would have to be developed and declared as a so-called offered service on LMS-side. Furthermore, an LMS-sided feature for retrieving performance information from RAE based on the data within the notification has to be developed.

Different learning scenarios require different integration strategies. In many cases, it is sufficient to return a simple score back to the LMS, but complex game-based or competence-based learning concepts require detailed information about a student's actions during a gameplay. The following sections describe two typical use cases.

A. Basic Use Case: Simple Integration of a Game into an LMS

A browser game or a game asset which is hosted by a gaming platform is embedded into an online course provided by an LMS. The transfer of user-specific gaming data is limited to a simple outcome like a score. In this case, on LMS-side LTI-functionality like Moodle's LTI-Consumer Plugin (see section III.C) can be used for authorization, authentication and tool launch. If not already provided by the LMS, only a web service for storing the final score in the student's gradebook has to be implemented. Competences can only be assigned in relation with this score; for automating this process, rules have to be defined and implemented. Ideally, configurable parameters like a maximum number of attempts and conditions for overwriting an existing score should also be provided. Regarding competences and QBL, the LTI-integration of the legacy software FUH-WebAssign described in section III.D is a sample scenario for the basic use case.

B. Extensive Data Exchange between LMS and Gaming Platform

To take advantage of the data that have been tracked during students' gameplay a more adaptable integration of the game is needed which implies an extensive data exchange between the LMS and the gaming platform. Ideally, the gaming platform enables game designers and authorized users like course authors or teachers to decide themselves, what has to be logged. This can be achieved by providing appropriate APIs and configuration dialogues. The RAE, which is based on the gaming platform e-Adventure [7-9], integrates the configuration of player-tracking into the process of game design and thus provides excellent conditions for generating useful information about a player's performance.

By making player-tracking configurable, the gaming platform indirectly supports competences and QBL: it just has to be specified, in which situations competences have to be attested. Ideally, standardized qualifications from well-established competence frameworks are used because they have a unique identifier. The gaming platform does not have to support competences and competence frameworks; its responsibility ends after transferring the tracked data back to the LMS. On LMS-side, user-specific performance data have to be mapped to competence structures. This requires an LMS-extension for QBL-support; the Moodle plugin conceptualized by Then et al. [3-5] could be extended for that purpose.

A sample workflow for connecting an LMS with RAE:

1. Instructional design of the lesson plan, including activities that put into practice one or several competences. Each competence must have a unique identifier.

2. The lesson's instructional design and the specific learning goals for the game will be the input for the game design phase, during which a game design document and an instructional design document are produced. The former focusses primarily on gaming aspects and tasks like picking the right game mechanics to address the desired goals. The latter includes, among other things (context, learning scenario, environment, etc.), specifications about how to assess players' skills and attest competences inside the game. These documents are the input for the game development phase.

3. As result of a gameplay, some metrics and insights into the players' attempts for mastering the given challenges are generated with RAGE Analytics.

4. Furthermore, the LMS is notified about the students' success at achieving the assessed competences by using a suitable API. A data structure like a sequence of tuples, each tuple providing a competence-id and a rating, would be sufficient. As the LTI outcomes service is limited to a simple score, an LTI-based solution would require a Tool Proxy which specifies LMS-sided services.

5. On LMS-side, the transferred data have to be mapped to competence structures; this requires a suitable QBL-extension.

V. CONSIDERATIONS ON A PROTOTYPICAL IMPLEMENTATION

From the perspective of QBL, we consider the second use case for our prototypical implementation, because it implies an extensive data exchange between the LMS and the gaming platform. This requires LTI-v2.0-features like Tool Proxies [1] and specific web services on LMS-side.

The LMS of choice is Moodle [2]. The LTI-Consumer-Plugin described in section III.C enables course authors to integrate external resources as Moodle activities of type External Tool. Since Moodle v3.2, advanced LTI-features like Tool Proxies are supported by standard, but a Moodle-extension has to be implemented nevertheless. Besides web services for receiving data from the RAE [6,10], it has to provide functionality for interpreting these data and mapping

them to (QBLM-compliant) competence structures. As our QBLM-extension for Moodle [5] is not yet fully implemented and we do not want to postpone the tasks described in this paper, we start with a temporary solution: since v3.1, Moodle offers basic support for competences and competence frameworks, see [5,29], so in a first step this environment will be used for our prototype. As soon as the QBL-plugin with its mapping between Moodle- and QBLM-competences [5] is available, the temporary solution can be adapted. This two-step process is transparent for LTI Tool Providers and will not cause any additional effort concerning interfaces and submitted data on RAE-side.

The game assets to be integrated into the LMS are provided by the RAGE Analytics Environment [6,10][6]. Single Sign On and tool launch via LTI are already implemented. A capable notification mechanism for realizing extensive data exchange is in progress, for details see section III.E.

VI. Summary and Future Work

In this paper, we have described an approach for combining the concepts of game-based and competence-based learning. The key component is a bidirectional connection between LMS and gaming platform. A special property of this connection is that the interaction is implemented according to the e-learning standard LTI. This means that resources like games and game assets can be transparently embedded into the LMS, an SSO-technology is used for authentication, and the gaming platform can send data about users' gameplay back to the LMS. Based on the tracked data, competences can be assigned to students.

The RAE already supports this kind of interaction, so it will be used as a reference gaming platform for our prototypical implementations. The LMS of choice is Moodle, which comes with LTI-Consumer functionality by standard. Based on these software systems, a solution has to be developed and implemented which improves the interaction between the involved systems in a way that allows for attesting competences to students.

In section II, LTI's limited possibilities regarding data transfer between embedded tools and LMS have been stated as the major problem of our idea, so the main challenge and research objective of our project is to find a capable, LTI-based solution for an extensive data exchange. In this context, the requirements on user tracking during gameplay sessions have been analyzed and appropriate modifications of the RAE's tracking mechanisms have been designed. Furthermore, an LTI-compliant concept for transferring user-specific, competence-based gameplay data from RAE to Moodle has been developed. On Moodle-side, the transferred data have to be mapped to QBLM-compliant competence structures. At the moment, our solution remains on a conceptual level, a prototypical implementation is not yet available.

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