

Innovative Authoring Tools for Online-Courses with Assignments

Integrating Heterogeneous Tools of e-Learning Platforms into Hybrid Application Solutions

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Abstract—This paper is concerned with an essential topic in e-learning - course content authoring. Besides supporting the concept of *Competence-Based Learning (CBL)* our solution is aiming to make effective use of an open integration architecture fostering the interoperability of hybrid e-learning solutions. Modern scenarios ask for interoperable software solutions to seamlessly integrate existing e-learning infrastructures and legacy tools with innovative technologies while being cognitively efficient to handle. In this way, prospective users are enabled to use them seamlessly without learning overheads. At the same time, methods of *Learning Design (LD)* in combination with CBL are getting more and more important to produce and maintain easy to facilitate solutions. Our approach of developing a competence-based course-authoring and assignment-support software bridges the gaps between Moodle and established legacy infrastructures by embedding existing legacy tools via *Learning Tools Interoperability (LTI)*. The underlying conceptual architecture for this integration approach and its components will be introduced; furthermore a Moodle plugin will be outlined, which enables Moodle for LD- and CBL-support including corresponding data exchange with our course authoring tool. The paper concludes with an outlook on future plans for our research and development.

Index Terms—course authoring, Moodle, CBL, LD, LTI, competences, distance-learning, LMS, LCMS.

I. INTRODUCTION, MOTIVATION AND APPROACH

Learning Management Systems (LMS) as well as *Learning Content Management Systems (LCMS)* nowadays are essential elements of *Higher-Education Institutions' (HEIs)* educational infrastructures. Driven by this trend, innovative learning scenarios emerge while triggering the evolution of this kind of e-learning software systems and corresponding overall academic teaching and training infrastructures. At the same time, innovative features in such educational software systems can (and should) inspire ambitious ideas for further developing teaching- and learning concepts or organization corresponding software application scenarios, so that the development of e-learning-software constantly progresses. In this way the needs for cognitive efficient and at the same time technically interoperable, transparently usable tools to support effective learning content creation and consumption approaches of their users are growing.

A rapid improvement of these technologies is appreciated, but it is coming with a price-tag: users with an intuitive approach to modern technologies might perceive the learning processes for the usage of a new software as an obstacle, and so it is desirable that formerly accustomed workflows are changed as little as possible. To learn the handling of new interfaces and programs, tutors, teachers, and professors - especially when they are not working within the field of information technologies - need to invest a distinctively high amount of time to get familiar with every piece of unknown software in their scholastic infrastructure. Therefore it is crucial to keep the learning curve as flat as possible. Even if the recent developments might help to work more efficiently and effectively: in the end, there are still too many hours to invest in learning new skills: these hours are lost for educational processes.

Modern learning scenarios do not only require teachers and faculty to get familiar with - also students need to learn about available technologies and services; teachers are constantly faced with students' questions about new platforms, features and add-ons, so that a certain amount of their teaching time goes into explaining the bits and pieces of most-recent learning tool developments to their students. Especially in adult education and if students do not belong to the generation of so-called *digital natives*, they often fail to understand the use of new platforms quickly enough to allow for a satisfactory learning experience.

While new tools for the development and evolution of e-learning infrastructures and learning environments are needed, students and teachers should not only be embraced by the change but feel inclined to try out new features without being confronted with having to study bulky manuals for every single feature of increasingly growing platforms or software-packages, such as, e.g., the LMS and LCMS *Moodle* [1].

Depending on the organization of HEIs, teaching fellows are employed to ease the way into new technologies for students and to help with the process of studying as such. However, as teaching fellows eventually are recruited from the experienced student-corpus, they typically stay for a limited amount of time in this job position resulting again in a towering amount of paid working time which is lost when they leave from their position. The problem of such high fluctuation of costly

trained and specialized workforce emerges frequently and adds to the work load of the permanent staff.

As a consequence, for example, an easy to learn and use *Course Authoring Tool (CAT)* for producing content for LMSs would not only help to save time and trouble for the teachers, but would also help HEIs to save monetary resources in training teaching assistants.

Along with the so-called *Bologna Process (BP)* [2], lectures are provided with academic credit points according to the *European Credit Transfer System (ECTS)* [3]. Furthermore, the skills conveyed by a lecture have to be stated and categorized in a determined way by assigning so-called *Competences*. This scheme is a binding standard for all accredited courses by European universities and colleges participating in the BP, in order to enable students to integrate a greater flexibility into their curricula. Contemporary learning environments therefore have to offer the best possible support for such requirements, meaning that online courses and learning content have to be tagged as knowledge resources with competence information. A lot of research on this topic has been done in the context of the TENCompetence project [4].

For more than 40 years the *University of Hagen* (German Fern-Universität Hagen, in short *FernUni* or *FUH*) with today more than 75.000 students the largest distance-education university of the German-speaking countries is a stately acknowledged, accredited and publicly funded HEI, providing education at an academic level via distance learning technologies. Besides the core software systems like an in-house developed campus management system and an enhanced, FernUni-specific Moodle-version with about 70.000 users and single courses exceeding 10.000 participants, numerous additional learning tools are provided. This includes a video portal, a wiki, and several communication tools as well as the legacy assignment software *WebAssign (WA)* [8] [9], which originally has been developed at FernUni's department of Mathematics and Computer Science at the Chair of Software Engineering. In addition to facilities and online resources, printed material is delivered to every student's doorstep. Professors, teaching fellows, tutors, and graders help students along their different journeys towards the aimed academic degree or certification. Different assignment types have been developed to engage students in learning processes and communication. The grading of these assignments is partly managed by the virtual learning environment, and partly done by graders.

II. PROBLEM STATEMENT, RESEARCH QUESTIONS, OBJECTIVES AND APPROACH

This paper will outline a concept for developing an effective and at the same time powerful learning content authoring software, which provides support for competences in the meaning of the BP while integrating different technologies transparently so that it will be comfortable and cognitively efficient to handle for non-computer scientists. The approach is optimized for the particular needs of educational institutions like FernUni, which process their lecture by using virtual learning environments; consequently distance education at FernUni will be taken as a first use case scenario.

The project can be divided into three parts:

- Connecting platforms like LMSs with particular e-learning tools, for example legacy assignment software;
- Developing a *Course Authoring Tool (CAT)*, which offers a user-friendly way to create and modify learning content for LMSs;
- Supporting advanced solutions for managing and categorizing learning content.

A. Learning Management System Moodle

Since Moodle [1] is widely known and used as a LMS and LCMS, FernUni is already using it since a while in several areas of its educational environment. Other than the proprietary competitor *Blackboard* [5], Moodle as a so-called *Open Source Solution (OSS)* is the platform of choice for our experimental scenario. Moodle as an LMS and LCMS in combination with several other tools is considered a powerful and at the same time open and flexible base system for our research.

Within its course model, Moodle supports many so-called *Moodle Activities (MA)*, offering features like assignments, forums, chat rooms or wikis. All these activities are implemented as so-called *Moodle Plugins (MP)*. They are sufficient for most requirements, but they do not offer the same comfort and variety of functionality as specialized software focusing on a single aspect of e-learning support, and so it is necessary to connect external tools and platforms to Moodle to be enabled to use both: the advantages of Moodle and the best features of additional learning tools and platforms. The Moodle open-source software-development community has identified these needs and created a plugin for this purpose, using the technology LTI [6] [7].

B. Connecting Moodle with External Learning Tools

To get an idea of the need for - and requirements towards - additional tools to be integrated with the already existing Moodle tool suite, we have interviewed teachers, staff and students at FernUni. These interviews have led to the conclusion that legacy tools still do play a significant role, in particular the assignment software WA. Several online tools have been developed during the last decades at FernUni, which are individually tailored to the needs of faculty and students. Most of these initially used in-house software solutions are - at least to some degree - outdated today, and quite a few even have been replaced lately, but some of these legacy tools are still in use and moreover: widely accepted.

Especially in the case of WA, an assignment tool supporting FernUni-specific workflows, it is not easy to find an alternative. Besides this, numerous teachers used it for decades and therefore have spent a significant quota of time for developing their assignment-scenarios and teaching-environments; these users would be, to say the least, dissatisfied with a mere replacement, and so WA will be kept as a legacy tool: ideally embedded or transparently integrated into Moodle.

The development will be directed to the use of WA as an LTI provider. The aim is to integrate it into Moodle and use it in addition to Moodle's assignment plugins. As far as possible, the connection between Moodle and WA should obtain the look and feel of a MP, more precisely a MA. When launching the activity, ideally users should not even notice that they are working outside of Moodle now.

A first step to find a solution is to explore the possibilities and features of the LTI standard which, according to its developers in [6] [7], specifies a way for integrating learning applications into e-learning platforms. The effort for making software like WA compatible to LTI seems to be maintainable and - regarding the benefit - justified. A requirements analysis and system integration specification for embedding WA into Moodle via LTI will be discussed later.

C. User-Friendly Course Authoring

Course creation should be attended by a user-friendly and easy to handle authoring tool. The overall goal and initial objective of our research work is to develop an authoring tool for Moodle courses, which will make it easier for teachers to intuitively create new learning scenarios in Moodle, aiming for a genuine user-interface supporting the *What-you-see-is-what-you-get (WYSIWYG)* paradigm while at the same time supporting the integration of additional resources into such Moodle courses based upon the LTI technology.

D. Competence Based Learning

FernUni supports advanced training programs in addition to academic courses concerning regular study paths. More often than not, these programs run in cooperation with external institutions, which - in several cases - have their own e-learning platforms. One of them is heading towards supporting CBL scenarios [4] [10] [11] [12] and therefore would appreciate the integration of advanced solutions for managing, categorizing and exchanging learning content into Moodle.

Supporting CBL affects the way to integrate external tools like WA into Moodle, because CBL specific information has to be inserted and shared. The exchange of CBL metadata is currently not supported by LTI, hence

a solution going beyond these limitations of LTI has to be found.

III. STATE OF THE ART AND TECHNOLOGY

Former research projects already worked on related problems and therefore in a few cases offer partial solutions for our objectives or appropriate starting points for further development. These are:

- the *TENCompetence Personal Competence Domain Model (PCDM)* [10];
- the *GLOBIT Ecosystem Portal (EP)* toolkit [14];
- *IMS Learning Tools Interoperability (LTI)*, see [6] and [7];
- Moodle and its *LTI Consumer Plugin* [13].

A. TENCompetence Personal Competence Domain Model (PCDM)

The PCDM has been developed in the scope of the TENCompetence Project as a part of the *Personal Competence Manager (PCM)* [4] [12] [16] [17], an open-source software which is based on Liferay [18] and supports CBL. The class model underlying this software is called the *Personal Competence Domain Model (PCDM)* [10]. Our former publications [22] and [21] include a detailed analysis of the PCDM and in [19] and [22] the state of the art regarding CBL is described in detail.

In Figure 1 the relevant cutout of the PCDM is displayed. The 'blue part' is responsible for modeling learning content like courses, activities and resources. It is based on *IMS Learning Design (IMS LD)*, a common specification which has been developed at the *Open University of the Netherlands (OUNL)*; the first version was published in February 2003 [23]. IMS is a shortcut for the *IMS Global Learning Consortium* [25]. LD bundles a wide range of existing e-learning standards and allows the

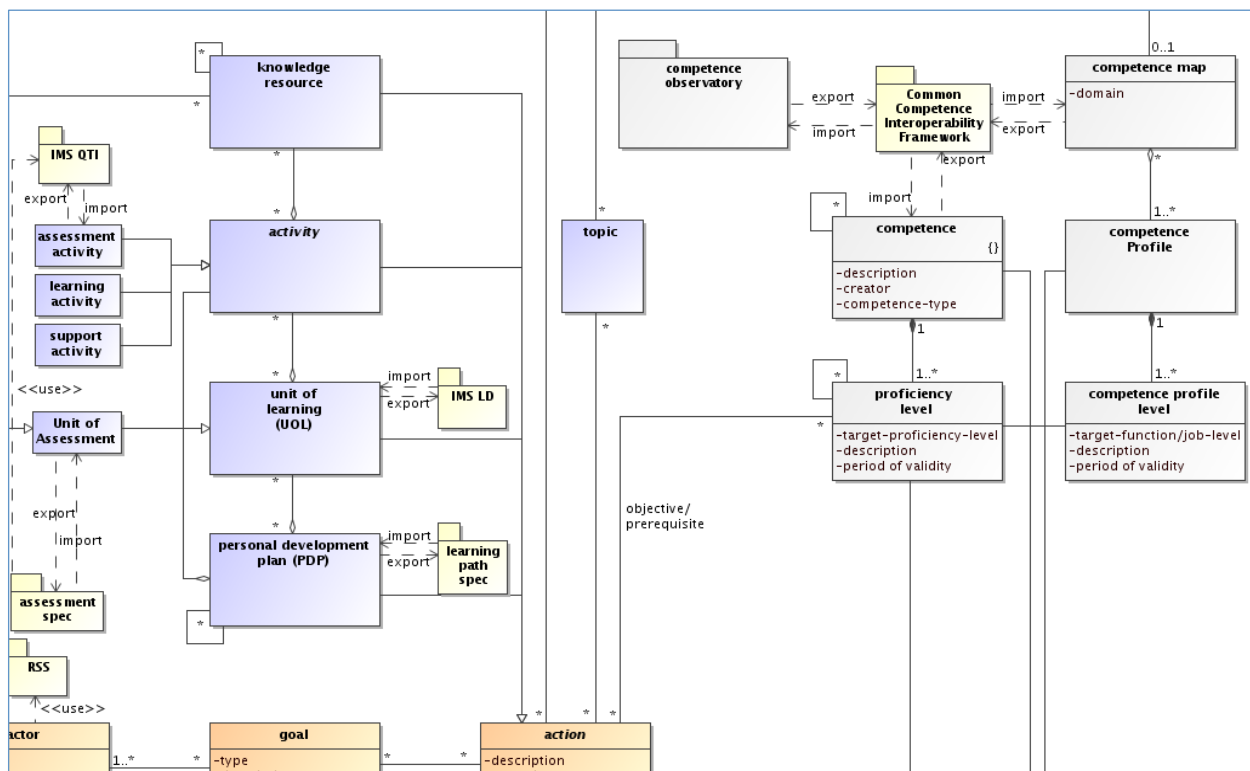


Figure 1: UML Class Diagram [36] of the TENCompetence Domain Model; cutout [10]

modeling of different learning strategies by using just a single language [24].

IMS LD uses the metaphor of a stage-play - also called *Unit of Learning (UOL)* - to model learning designs. A UOL represents an enclosed educational part like a course, module or lesson, with pre-defined *Learning Goals (LGs)*, and consists of one or more *Learning Acts (LAs)*. An act on its part contains different *Learning Activities (LAs)* as reading texts or discussing the subject with peers. *Learning Resources (LR)* and their files represent the requisites of the stage-play.

The PCDM extends IMS LD with support for Competence Based Learning. The classes in the 'grey area' in Figure 1 contain CBL information, which can be connected to learning content by the association *objective/prerequisite*. A *Competence (C)* is the acquired or perceived skill of a person, group, or an organization to handle critical events, problems, or tasks in certain situations. Competences are graded into *Proficiency Levels (PL)* [15]. An example for a competence from within computer science education could be 'relational database systems, pl2'. A collection of competences to handle problems in different situations is called *Competence Profile (CP)*; analogue to competences CPs are graded into *Competence Profile Levels (CPL)*. For example the CP 'software developer in c++, cpl2' could contain the competences 'relational database system, pl2', 'programming in c++, pl3', 'concepts of oop, pl2' and 'software engineering, pl1'.

Another software solution claiming to support Competence Based Learning is the *Educational Portal* toolkit, which has been developed by the software company *GLOBIT* [14] and is currently extended into an *Ecosystem Portal (EP)* toolkit by the research institute *Forschungsinstitut für Telekommunikation und*

Kooperation (FTK) [26] in the European coordination and support action *RAGE* [27]. It is based on the CMS *Typo3* [28] and will offer extensions for the use of competences and learning goals in the foreseeable future. Furthermore, a wide variety of useful tools is already provided by now (see Figure 2), including a web-based, user-friendly course authoring tool called EP-CAT, which is an appropriate starting point for our authoring tool and therefore prevents us from re-inventing the wheel.

B. IMS Learning Tools Interoperability

LTI specifies a standard way for integrating learning applications such as forums, chat rooms, wikis, assignment tools and video-streaming into platforms like LMS, see [6] and [7]. In an LTI-context, tools are called *tool providers*, and platforms are *tool consumers*.

The recent LTI version is v2.0, which includes the features defined in versions v1.x, and adds additional functionality; the specification can be found in [6]. The following is essential for the development of our prototype:

- Launching external resources (since v1.0);
- Returning outcomes to consumer (since v1.1);
- For extensions concerning CBL support v2.0 will be required.

This section starts with an introduction to those features, followed by a description of Moodle's approach to support LTI.

1) *Launching External Resources*

An appropriate way to prepare a learning management system to install connections between courses and resources hosted by LTI-tool-providers is to use (or develop) an according activity-type, which enables the LMS to act as a tool consumer. In a Moodle course, such a

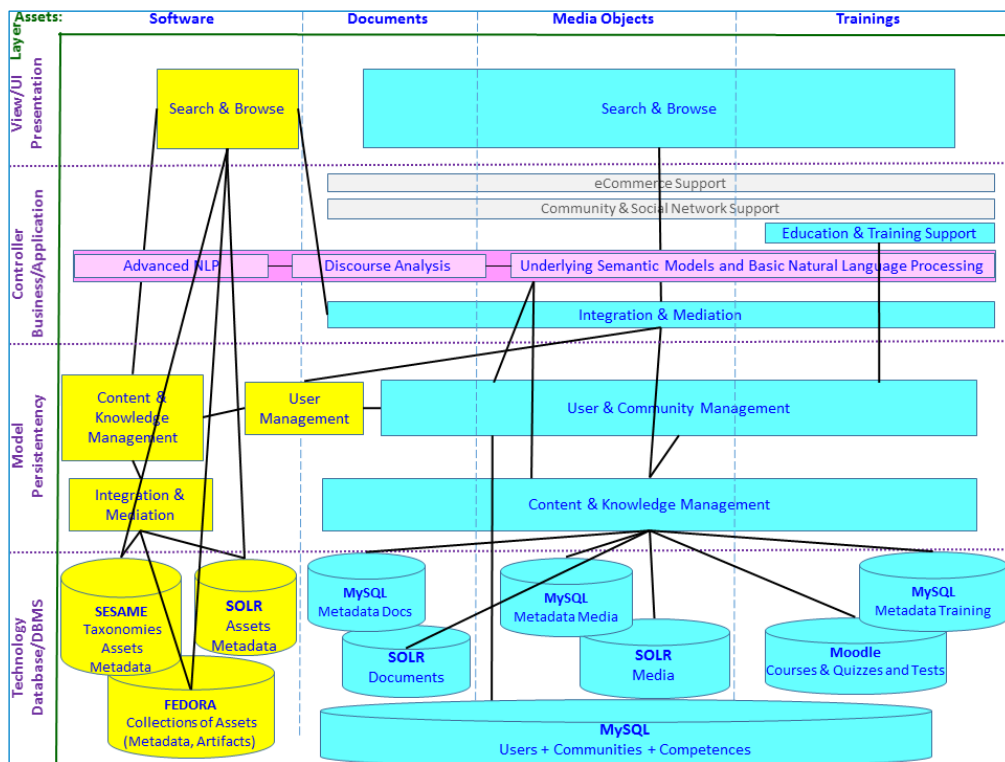


Figure 2: The Ecosystem Portal (EP) - an overview

connection is specified by an activity-instance of the type *external tool*, which contains authorization parameters as well as essential information like the URI of the resource to connect to - for example an assignment. When a user enters a Moodle course, the connection is represented by a link to the activity-instance so that for example a request for launching a certain resource is sent via mouse click.

To secure access, LTI uses the standard *OAuth*; this is a standard for authorization, which has been developed from the *Internet Engineering Task Force (IETF)* [29] [30]. The verification of a request works roughly as follows: On the consumer side, a request has been signed with a token, generated from the *consumer key* and the *shared secret*. The provider uses the *shared secret* to decrypt the token. In case the result is the consumer key, the sender is identified as Moodle, respectively a Moodle resource, namely an activity of type *external tool*. This is a strongly simplified description; in fact the procedure is much more complex.

Once the sender is authenticated, further parameters - such as user, context and role - will be identified. Until this stage, the request is only known as generated by a Moodle activity. The provider will handle the decision upon granting access to any demanded resource. If approved, the user will be logged in automatically, meaning that the provider will create a user session. The provider tool then can be launched inside of the requesting Moodle course - for example, in an *iframe* or a separate window.

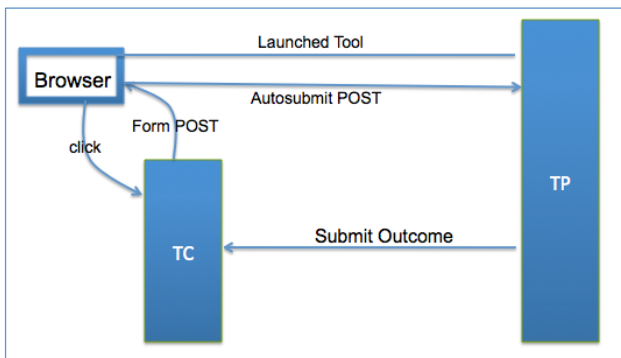


Figure 3: LTI Core Functionalities [7]

Figure 3 displays the process of launching a tool. A Moodle user starts this process by clicking on any link to an activity-instance of the type *external tool*, representing a connection between Moodle and a protected resource at the provider-side. In this example, the tool consumer 'TC' prepares the launch parameters, signs them via *OAuth* and then sends a message back to the browser from where it was originally posted. From there it is automatically - this feature is likely to be developed in JavaScript - forwarded to the provider 'TP'. The provider verifies the consumer via *OAuth*, and in the case of success, it checks further submitted parameters. If access is approved, the external resource can be launched inside of the requesting Moodle-course. For an example including a more detailed view on *OAuth* see [20].

2) Returning Outcomes to the Consumer

The tool launch is part of LTI since version 1.0. In v1.1 a procedure has been added, which specifies a way to return outcomes back to the consumer, see Figure 3. Its purpose is to enable learning platforms to receive

assessment information like scores and comments from the external tools. Moodle stores these information in the students' grade books.

The associated notification mechanism is completely asynchronous with the tool launch - a provider could for example transfer the latest results per cron job every few minutes.

3) New Features in v2.0

Returning outcomes back to the consumer has been the first feature in LTI including web services. Version 2.0 introduces additional services [6] [7] offering the following:

- A wider range of information and not just a score can be returned as the so-called outcome;
- Providers are enabled to inspect consumer-side resources like courses and course sections;
- Providers may check enrolments in consumer-courses;
- Providers can be configured to store data on the consumer-side.

Before LTI v2.0 returning outcomes had been the only feature, which allowed a provider (external tool) to return data to the consumer (e.g. a LMS). LTI v2.0 not only introduced additional web services on consumer-side, it provides a plugin-interface, which offers the possibility to extend LTI-connections by in-house developed web services in a determined way. The option of integrating in-house services could be the key for the information exchange concerning Competence Based Learning between WebAssign and Moodle.

From the viewpoint of security and privacy, some of the new possibilities can be regarded as critical. LTI offers a standardized way to define individual interface contracts between the involved applications. Such a contract, called *ToolProxy*, determines which services shall be used by the participants. This way, critical features may be blocked on each side of the connection by setting the configuration parameters accordingly.

4) Moodle's LTI Consumer Plugin

The idea of integrating external e-learning tools into Moodle is already supported; the Moodle community saw the potential of this technology and developed two plugins, see [13] and [31]. The plugin *external tool*, 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 still necessary.

In the context of our project Moodle will act as a tool consumer, and so the LTI Consumer Plugin will be the starting point on Moodle side. In recent Moodle releases from version 2.8 onwards LTI v2.0 is supported; earlier versions support LTI v1.1.

Creating such a connection can be quite simple, as long as the external tool supports LTI; on [32] a list of certified tools is available. Implementing LTI connections between Moodle and legacy software like WA implies making these tools LTI compatible. Several universities, for example the *University of Duisburg-Essen*, adapted their internal developed assignment software for this purpose. However, their tool *Jack* [33] is catered to the needs of the

University Duisburg-Essen and their way to implement LTI support does not suit to our requirements. Moodle itself can also be used as a tool provider: this requires the installation of the plugin described in [31].

To gain a first impression of working with LTI, we have built up a test environment containing two separate Moodle instances: Moodle A acts as a tool consumer, Moodle B as a provider. Figure 4 displays an example, where an assignment in Moodle B is used by a course in Moodle A. It probably would make sense to suppress the header and the blocks of Moodle B. Anyhow, for demonstration purposes both Moodle instances are displayed. When launching the assignment, the active user in Moodle A is automatically logged into Moodle B. The login procedure itself is handled completely by the provider.



Figure 4: Two Moodles, connected via LTI

The LTI Consumer-Plugin offers a service for receiving information such as scores. Moodle's provider plugin periodically requests this service per cron job, which identifies new results and transfers them back to the consumer. Finally the information does not only exist on the provider-side but also in the Moodle course's grade book.

Since Moodle version v2.8 the LTI Consumer Plugin supports LTI v2.0, and an interface for integrating further web services is available. This offers a way to exchange competence information between Moodle and tool providers via in-house developed services.

5) Benefits for Institutions

Each involved group, such as software developers, administrators, teachers and students, can benefit from LTI in different ways: A developer of external tools does not need to have a deeper understanding of the providing platform itself, and might handle it as a black box. Furthermore, he or she is free to choose the preferred language and IDE for any development process. Probably the most important advantage is that a single user interface is suitable for each consumer.

The administration of a learning platform, usually a learning management system, profits from LTI as well. It is no longer required to install and test different integrations for each tool-provider. Besides, security and performance of the LMS are not affected, because the connected tools are running in separate environments. Besides, updates of the LMS are less risky as long as the underlying LTI extension is not corrupted by an update.

Another helpful feature (depending on the know-how of the involved users) consists in the possibility to authorize teachers to add LTI connections all by themselves.

Last but not least teachers and learners benefit from LTI, because it minimizes the necessary effort to use external applications with learning management systems. Furthermore, the choice of tools is only limited by the institution, encouraging the creation and development of other applicable e-learning tools. This process nourishes an environment for improving the quality of modern education.

IV. SYSTEM DESIGN AND METHODOLOGY

It can be said that an innovative software solution which is going beyond the state of the art has to be developed, and so the following requirements have to be considered:

1. Integration of external tools into Moodle via LTI, including meta-information for CBL support. As a proof of concept, WebAssign will be embedded into Moodle.
2. Development of an extended CAT offering a user-friendly way to create and modify Moodle courses. It will be based on the EP-CAT.
3. The CAT has to run in an environment, which equips learning content with competences and competence profiles, therefore dealing with CBL information based on the PCDM is obligatory.
4. Moodle is the platform, where the courses take place, so course data together with integrated CBL information have to be transferred from the CAT to Moodle; a mechanism for exporting/importing those data, has to be provided.

At the beginning, some fundamental considerations and decisions concerning the architecture have to be made. CBL compliance is a core requirement, so an appropriate way to handle and exchange competence information has to be found. This affects our CAT as well as Moodle and additional learning tools embedded via LTI.

A. Architecture

The domain class model used for the approach presented in this paper is based on the *Personal Competence Domain Model*. Modification of the PCDM is necessary, because it does not consider distributed solutions like LTI yet, and its *import/export-interface* for *Units of Learning* is limited to IMS LD - so it offers no support for the exchange of CBL information with other systems, see Figure 1. Unlike IMS LD, it does not contain a class *Act* or *Activity-Structure* to divide a UOL into different *Sections*, which can lead to conflicts when exchanging data with an LMS.

In Figure 5 two additional classes are introduced to the PCDM - *Act* and *External Activity*. As Moodle and most other LMSs divide courses into smaller units - in Moodle called *Sections* - a corresponding class has been added and named *Act* in analogy to IMS LD. The class *External Activity* enables the PCDM to integrate resources from external learning software via LTI connections. It inherits the properties of the abstract class *Activity* and adds some information, which define a connection between a UOL and an LTI resource.

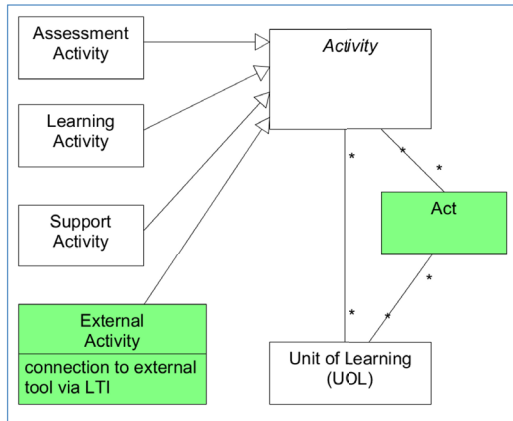


Figure 5: UML Class Diagram [36] - PCDM-extensions
 External Activity and Act

To provide PCDM's *IMS-LD import/export-interface* with support for the exchange of CBL metadata, an appropriate extension has to be introduced, see Figure 6. In addition or as an alternative to that xml-based exchange format, *Moodle's Webservice-API* could be used.

Figure 7 displays our architecture consisting of three main components, which form the corner points of a triangle:

- The Course Authoring Tool (CAT)
- Moodle with its plugins and its webservice-interface
- External learning tools, represented here by our legacy software WA.

This architecture assumes an extended PCDM and implies the elements presented above as well as suitable web services in Moodle.

External learning tools have to act as LTI-tool-providers, therefore LTI-support is required. Ideally, this includes extensions for exchanging CBL metadata, but this should be optional, otherwise it would limit the choice of available tools in a significant way.

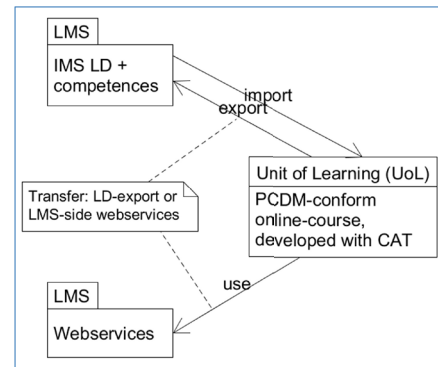


Figure 6: UML Class Diagram [36] - PCDM-extension
 for LD-Export and web services

B. Embedding WA into Moodle

This section presents a case study for the integration of legacy learning tools into Moodle - the connection between Moodle and WA. In LTI jargon Moodle is the *tool consumer*, because it accesses resources from the external tool. WA provides these resources; so it is the *tool provider*.

The Moodle side of this connection will be less problematic, since Moodle already offers appropriate support with its LTI Consumer Plugin. In addition to LTI's core functionality, it offers the possibility to integrate additional web services in an LTI compliant way by using the intended interface. Therefore, implementing and introducing suitable web services should be sufficient

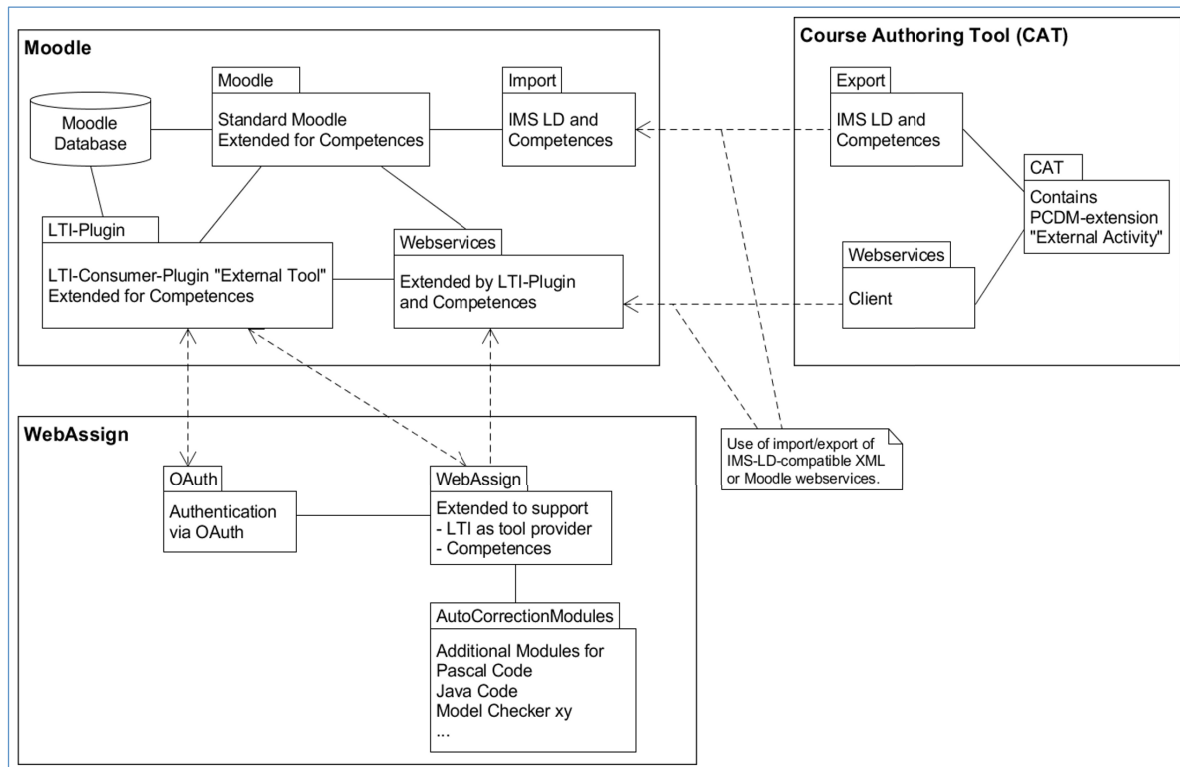


Figure 7: Software Integration Architecture

for our purposes; modification of the plugin itself will not be necessary.

From the provider side a considerable effort has to be taken into concern, because like most legacy software, WA does not support LTI yet. First of all, a requirements specification including decisions about the capability range of the Moodle-WA-integration is needed. Apart from this, authentication via OAuth and transferring outcomes from WA to Moodle are obligatory.

1) Requirements and Decisions

A typical course at FernUni is divided into four or seven units - depending on workload and credit points according to the ECTS [3]. This scheme is a binding standard for all accredited courses by European universities and colleges; it enables students to integrate a greater flexibility into their curricula due to the comparable competences-measurements with credit points.

Each unit of a FernUni course contains an optional exercise booklet. These booklets serve as containers for assignments. Since this structure has been part of the requirements for the development of WA decades ago, it is perfectly integrated into WA. A disadvantage of this structure is that WA is limited in its way of organizing assignments outside of the scheduled units-plan, which is a barrier for asynchronous studies. Concerning the LTI support it has to be decided if single assignments, whole booklets, or both possibilities should be integrated.

The core feature of the connection is to launch a WA resource from within a Moodle course without disturbing the user's workflow. The research is in the state of investigating the possibilities and needs - mainly by focusing on didactical aspects, focusing on the fact that new authoring tools are developed to support teaching and learning processes. Up to now it is unclear, which types of resources and which workflows shall be opened for Moodle:

- Students working on their assignments;
- Teachers creating and editing assignments;
- Teachers using the correction workflow.

Since students should not be aware of WA as an underlying platform, the first listed workflow is essential here.

Several assignment types require manual marking by a grader, who in some cases also writes reports and statistics. In addition, quite a few tutors, mentors and teaching fellows use a point-system along with quizzes and assignments - either to show the students their learning performance, or to create a filter by having a minimum of assignments-points set to allow only students who meet these minimum requirements to participate in a final exam. Assignment booklets are usually handled as pdf files. WA offers a capable workflow to manage the marking process - including features like the automatic distribution of assignments between teachers and graders. The distribution modes can be individually configured; this would be an advantageous feature in Moodle, making the usability of external tools even more desirable.

WA also offers an interface enabling teachers to employ additional tools for checking students' answers to assignments and problem sets, as they - for example - occur in the field of computer science. In WA, teachers

may integrate their own analyzers for verifying and testing program code, written in Pascal, Java or C++. These kinds of additional tools will probably not affect the development of connections between Moodle and WA directly, but they should be kept in mind for further improvements.

2) Considerations and Technical Aspects

Resource owners in WA need an interface to authorize and withdraw LTI connections.

LTI requires OAuth support, which is currently not available in WA, so an appropriate extension has to be discovered and installed. Successfully OAuth-verified requests have to pass some further checks:

- Sender: The sender needs to be identified, and data must be compared to the list of verified WA users. Furthermore, it has to be checked, if the sender is authorized to access the resource.
- Requested resource: An approval of the request is needed, because several resources only have a granted access during limited time periods.

If the access is permitted, the sender has to be logged in automatically, which includes creating and initializing a secure session. Next step is to generate a browser-readable presentation of the requested resource.

Last but not least a workflow for returning outcomes to Moodle has to be developed. As this process will be asynchronous, a possible solution might be to execute a cron job on a regularly basis.

C. Moodle Plugin for CBL

The architecture displayed in Figure 7 requires Moodle to receive learning content with competence information from the CAT, for this reason suitable import/export-functionality has to be provided, Figure 6 shows further details. From a developer's point of view, there are three possibilities:

- Implementing an xml-parser for LD and CBL information exported by the CAT;
- Using available Moodle web services and writing additional ones for transferring competence information;
- A combination of both.

A first step to tackle this task is to identify distinct relations between the CAT's PCDM-based class model and Moodle's database tables. Moodle does not work object oriented in the case of courses and activities, so on Moodle side there is no domain class model, which could be used. Based on these relations CAT-content can be transferred to Moodle; below a Moodle extension providing such a mapping is presented.

The diagram in Figure 8 displays the involved database tables in the form of domain classes with orange background. A comparison between these tables and the extended PCDM (Figure 1, Figure 5) indicates, that every PCDM-element involved in the exchange of CBL information has a counterpart in Moodle:

- unit of learning → course
- act → course section
- activity → course_module
- knowledge resource → files

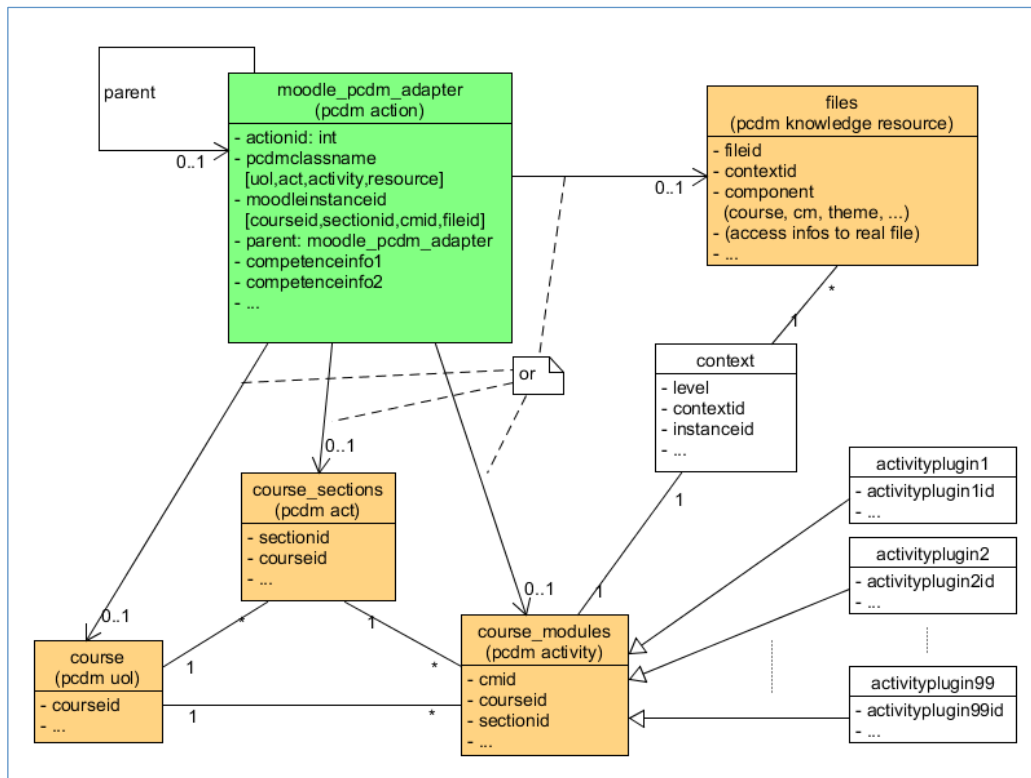


Figure 8: UML Class Diagram [36] - Mapping from PCDM to Moodle

The database tables *activityplugin1..99* are standing for Moodle-Activity-Plugins like forum, quiz, wiki and many more.

Developing a plugin appears to be the method of choice for integrating CBL extensions into Moodle, because its plugin-interface enables programmers to add new functionality without touching the core code. In fact, most Moodle features, for example all activities, repositories, and filters, are plugins. Encapsulating the core code and adding extensions over a specified interface reduces the risk for side effects and improves the flexibility and maintainability of a Moodle installation, for example in case of upgrades.

Implementation of a mapping from CAT conform learning content with CBL information to the Moodle database requires new, plugin-specific tables on the side of Moodle, which extend the core tables with competence specific structures. The table *moodle_pcdm_adapter* in Figure 8 acts as the counterpart to the abstract class *action* in the PCDM (see Figure 1), serving as a bridge between learning content and competence information.

The mapping from CBL elements like competences and learning goals to Moodle is still in the state of development. Moodle's *outcomes*-feature [34] seems to be an appropriate starting point for extending courses, activities and resources with PCDM compliant competence information.

D. Course Authoring in CAT and Moodle

Relying on a particular learning content authoring tool with an easy and intuitive user interface implies that Moodle courses will be created from outside of Moodle and have to be transferred to Moodle in one way or the other. As previously described, this requires a Moodle extension - ideally implemented as a plugin. For loosening

the dependency between CAT and Moodle to a certain degree, this plugin may be equipped with a simple user interface offering some basic features for creating and editing courses on the side of Moodle. Encapsulation of the plugin's application logic in the meaning of the *Model View Controller (MVC)* [35] software design pattern opens the possibility to create courses with CBL support from different user interfaces, including the CAT and Moodle itself. As an example for this approach, we have developed a slim plugin, which enables Moodle to clone an eligible course with one mouse click. Cloning can be triggered from a user interface within Moodle or from a web service, which can be called by external authoring software like the CAT.

V. SUMMARY AND FUTURE WORK

Several key issues of our research goals, requirements, state of the art and approaches have been presented. Along the state of the art in this paper, we have identified Moodle, LTI, the PCDM and the EP as suitable fundamentals for our project. As our approaches go beyond these technologies, appropriate extensions are inevitable; some of them have been outlined in this paper.

Based on our integration architecture which makes use of these extensions, we started developing our concepts. It can be stated that our project divides up into several parts:

- Integration of external e-learning tools into Moodle via LTI;
- User-friendly CAT based on GLOBIT's EP-CAT;
- Extending the CAT for support of CBL;
- Moodle Plugin for CBL support, which offers web services for data exchange with the CAT.

One key issue of this paper has been the concept for integrating external e-learning tools into Moodle via LTI. To gain the necessary technical expertise, experience and data for this research project, an LTI connection prototype will be designed and implemented from scratch, implying the extension of the tool provider for LTI support. Working with LTI ready tools is not sufficient in this scenario, because later the connection must be extended for the use of competences, making a deeper knowledge inevitable. The prototype will connect Moodle and WA; latter was the tool of choice, because its Moodle integration is demanded at FernUni.

Focusing on software architecture we analyzed the PCDM and proposed appropriate extensions concerning the support of external tools and data exchange with Moodle. The resulting class model is one of the key stones of our architecture.

Furthermore, we outlined a Moodle Plugin, enabling Moodle to deal with competences and exchange CBL metadata with particular authoring tools like a modified CAT. The design of this particular Moodle Plugin is not yet complete, because it depends on the solution for the management of competences and taxonomies, which is in development at the time being. Encapsulation of our plugin's application logic in terms of the MVC pattern offers the possibility to create and edit courses from within Moodle as well as from particular, more user-friendly authoring tools like the CAT.

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