

Distributed Platform for e-Learning – DisPeL

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Abstract

This paper describes a distributed platform for e-learning (DisPeL). The administration of the learning process and adaptability of the learning content are emphasized as key elements of the platform, which differentiate it from the other e-learning systems. Detailed overview of these two components is made. The paper outlines the model, architecture and user roles of the platform. DisPeL is successfully implemented into several universities in Bulgaria.

Keywords: e-learning, e-testing, learning administration, adaptive learning content, DisPeL, DeTC

1 Introduction

In this paper we describe the model, components and services of a distributed platform for electronic learning - DisPeL. We provide a combination of components that enables the conduct of a complete learning process from organization of the learning process to assessment and completion of the learning.

The demand for electronic learning services is not limited to higher learning institutions. Public organizations and business companies have increasing needs to provide and consume learning services. Therefore, our platform is developed as a multi-tenant web application. Multi-tenancy allows the platform to be used as software as a service (SaaS).

The primary components of the platform are developed as SOAP and RESTful web services, which enables interoperability with other tools regardless of the technology. RESTful web services allow future extensions of the platform with native or web-based mobile clients.

DisPeL is an evolution to DeTC [Rahneva, 2004b; Rahnev, 2005; Pavlov, 2006; Pavlov, 2010; Pavlov, 2012b] in the virtual learning space [Orozova, 2013]. DeTC was initially developed as a part of the Distributed e-Learning Cluster (DeLC) [Ganchev, 2003; Stoyanov, 2003a; Stoyanov, 2003b; Stoyanov, 2005; Stoyanov, 2006a; Stoyanov, 2006b].

There are three primary contributions of DisPeL:

1. It automates the management and administration of the learning process. Automation is achieved through a specialized information system. Administration of the learning process is integrated tightly with the learning process itself on both process and service levels.
2. Learning is enhanced via adaptability of the e-learning content.
3. It is implemented as cloud-based system following the software-as-a-service model.

The information system for management and administration of the learning process is a key component in our model. No education process can be successful without competent administration. At the same time, existing systems for e-learning are not servicing the administration process. Nowadays most efforts in the area of electronic learning are targeted towards providing novel instruments for consumption learning content. Many systems also include instruments to facilitate students in their everyday learning activities and communications with the other participants in the learning process. As a result, these systems have insufficient level of integration with the systems for administration of the learning process.

Our understanding that administration of the learning process is not a supplementary part of the learning. Instead, we believe that administration is a core part of the overall learning process, and without efficient administration it is not possible to have efficient learning.

Another important aspect of our model is the adaptability of learning content. Existing research has shown that application of adaptation can provide better learning environment in electronic learning systems. [Oppermann, 1997].

2 What is DisPeL?

2.1 Model

The conceptual model of DisPeL is based on cloud computing, and the Software as a Service (SaaS) cloud model, as defined by NIST [Mell, 2009; Voorsluys, 2011]. According to the reference model of Hamdaqa, cloud applications consist of a number of cloud tasks. A Cloud Task is a composable unit, which consists of a set of actions that utilize services to provide a specific functionality to solve a problem [Hamdaqa 2011]. The characteristics of cloud tasks make them similar to software components.

The model of the platform is presented by the follow four key cloud tasks (figure 1):

- Learning Administration.
- Web Auditorium.
- Adaptive learning content.
- Testing assessment and examination.

Despite that fact that Web Auditorium integrates its services with these of the Adaptive Learning Content and Testing Assessment and Examination modules, the latter two are stand-alone, feature-rich cloud tasks, and therefore are described separately from the Web Auditorium.

These tasks can be personalized and adapted to the specific profile of every customer: their educational needs, learning programs and courses, assessment and certification requirements, etc.

2.2 Architecture

The platform has pluggable architecture and its components (or cloud tasks) are loosely coupled. This means that every component of the platform can be developed and extended independently from the others, and even replaced with a completely new implementation, without affecting or requiring updates of the other components.

The architecture also enables flexible personalization, where a dedicated, personalized instance can be created for a customer, where one or more components are replaced with highly personalized implementations.

2.3 User roles

We define eight user roles.

- Learners.
- Tutors.
- Instructors.
- Invigilators.
- Assessors.
- Course administrators.
- System administrators.
- State educational administration offices.

The interaction between user roles and the cloud tasks is presented in figure 2.

A physical person can execute more than one role. For example, for smaller educational organizations it is common that a single person is a tutor, instructor, and assessor.

2.3.1 Learners

Learners are university students, school students, company workers and employees, etc. who seek learning and obtaining new knowledge and skills.

2.3.2 Tutors

Tutors are the authors of learning content. These are usually university professors, teachers, trainers or highly-skilled organization employees. They prepare the structure and content of learning materials and sessions. They can also prepare tests for assessment.

2.3.3 Instructors

Instructors are usually assistants to tutors. For example, these can be university professor assistants. Instructors contribute to the successful conduct of the educational process and test examinations.

2.3.4 Invigilators

Invigilators assist the examination and certification process by ensuring that the examination process goes under equal conditions and without cheating.

We also define that invigilators can be one or multiple hardware devices, which certify the personality of the examined learners, and prevent cheating. A finger-print reader or personal digital certificate can certify the personality of the learner. A 360-degree camera providing full space coverage with a microphone can certify the personality and protect against cheating. Monitor software can be used to supervise the activity of the examiner. Special software can reduce the access to external resources during examination – for example, firewall software can block access to the World Wide Web and prevent learners from using the Internet to find helpful information during the exam.

2.3.5 Assessors

Assessors are responsible for assessing the tests and registering the results of the tests.

2.3.6 Course administrators

Course administrators organize the learning and examination process. They collect and process the information about all users involved. They organize and schedule the learning sessions, and examination sessions. They are responsible for collecting the results of the examinations and issue certificates.

2.3.7 System administrators

System administrators support the hardware and software aspect of the learning process.

2.3.8 State educational administration offices

State educational administration offices are an external party to the learning process, but are always involved in the education, carried out by certified institutions like universities and schools. State administration defines the requirements, and requires periodic reports about the education and examinations.

3 Administration of the Learning Process

We realize that every organization will have its own specific requirements for the administration of the learning process. The specifics are determined by two factors: subjective and objective. The subjective factor is the very own operational model of the organization. Organizations have their own operational model, which is can be even one of their competitive advantages. While organizations can seek optimizations of this model, its complete change is rarely welcome. The objective factor is the legislation system under which the organization operates. In particular, official educational institutions need to follow a number regulations and meet requirements, specific for their country and region.

The pluggable architecture of the platform allows the platform to support different models of administration of the learning process.

A special module for Bulgarian universities is developed. It is fully compliant with the legislation in Bulgaria and the special requirements for Universities of the Bulgarian Ministry of Education – University Information System, or UnIS.

The system automates the work and the activities at the Registration Office of a University. It maintains all the needed data base elements entirely consistent with the requirements of the Bulgarian Ministry of Education and Science. UnIS covers the entire educational process – from application and enrolling to graduation of the students. The system provides a convenient and intuitive user interface which complies with the specific work of the Register's staff.

UnIS provides and maintains:

- Managing a set of roles for granting different levels of access to the functionality of UnIS – administrators, Register staff, officers, deans, etc.
- Handling the admissions process - enrolling new students; managing the teaching option choices, the records of the admission exams, evaluation and ranking; acceptance.
- Student's record – handling educational data, personal data, admissions data, etc.
- Full information about the student's academic progress – enrolment for study schedules and the corresponding courses, marks, academic status, participation in international educational programs, accommodation at students' hall of residence, getting a scholarship, health insurance status, etc.
- Detailed reports – grades for a semester for a particular course, failed grades; average grade, diploma references, academic transcripts, academic status references, paid/unpaid fees, various statistics, etc.
- Printing various documents (A4) – education verifications, examination records, individual examination documents, final graduate examination records (State examination records), lists, academic transcripts, diploma, diploma duplicate, diploma supplementary documents, etc.
- Grades and marks export - the system provides the ability to export grades to a University Web site, where the students can check their assessments and monitor their academic status.
- Data export – the system automatically generates all informational data text files, which are required to be periodically sent to the Ministry of Education and Science.
- Automation – UnIS has a number of automated processes which aid the University administration in their work: moving a group of students to the next study schedule, filling in the examination records, group enrolment in elective courses, export/import of data to/from other information systems, and many others.

- Data archiving – the system provides the ability to archive the system’s data –manually by the administrators or automatically (scheduled daily)
- Services to manage the web auditoriums (described below).

The system has an additional administrator module called UnIS Admin, where the system administrators can perform global maintenance, specific operations and queries, add and edit users and their access privileges to the system, generation of text files to be exported to the Bulgarian Ministry of Education and Science, etc.

UnIS is a distributed application with four-tier architecture, which can be used as a standalone application for administration of the learning process in Bulgarian universities. It is developed using a framework for distributed business application [Pavlov, 2006; Pavlov, 2011].

4 Web Auditorium

Web auditorium is a web-based system that provides a large range of services for tutors and learners. The system can be used both to support learning in regular and part-time education, and to conduct distance learning.

The core of the system is the web auditorium. The web auditorium is a virtual space where teachers and students join to participate in the learning process of one discipline. When a user logs in, he receives a list with all active web auditoriums. The list depends on the schedule and program of every user.

4.1 Features

The primary features of web auditoriums are:

- Learning materials – lecturers can add learning materials for the students from the lecture hall. The students receive access to the materials.
- Homework Assignments – lecturers can assign course works to the students (for all students, for a group, or individually). For each assignment, a deadline is set for students to submit their work. Students have access to the course assignments content and to the functionality provided by the system to submit their work.
- Messages – the system provides messaging - the participants of a virtual lecture hall can exchange messages.
- Live instant messaging chat.
- Live audio and video sessions.
- Access to offline video and audio materials.

4.2 Additional services for tutors

- Besides the functionality described in virtual lecture halls, the following additional modules are developed for the tutors:
- Manage learners – the module allows for separating the students, participating in a virtual lecture hall, into groups; provides generating and printing of lists and examination records.
- Mergewebeducation – enables merging a multiple web auditoriums into one. This functionality is used when groups of learners in different programs study one and the same course with the same tutor. Subsequently, the tutor administrates only one merged web auditoriums. This eliminates the necessity the tutor to upload learning materials and manage learners on same course multiple times at multiple places.
- Learning schedule – lecturers receive access to their schedule and, in addition, can add personal appointments and tasks to it. The module provides making inquiries and generating reports about a lecturer’s schedule for a selected time period.

- File manager – each lecturer is assigned a personal file space for storing all of his/her materials, which the lecturer can later add to the modules Study materials and Assignments, or just store for personal usage.
- Personal profile – the module provides the ability to add a photo, a phone number and an email address for contact. It allows setting up the events on which the lecturer would receive a notification by email – receiving a message, assignment submission, and news.
- Access to the adaptive e-learning content module to create adaptive learning content.
- Access to the test system module to prepare testing questions for testing self-assessment and examinations.

4.3 Additional services for learners

Besides the functionality described in virtual lecture halls, the following additional modules are developed for the students:

- Academic Reports – average grade, failed grades, simplified academic transcript.
- Certificates – the module provides functionality for the student to fill out and print certificate documents. Next, the document must be delivered to the Registrar's office for review, signature and stamp.
- Learning schedule – the module provides access to a student's learning schedule and calendar. There are two calendars – a general weekly schedule and a personnel calendar.
- Applications – this module is an automatic system that allows for preparation of template applications to the University management and administration body. The sent applications automatically receive an incoming number, date, and status, which can be traced.
- Personal profile – the module provides the ability to add a photo, a phone number and an email address for contact. It allows setting up the events on which the lecturer would receive a notification by email – receiving a message, assignment submission, and news.

4.4 Services for administrators, accessible from UnIS

UnIS provides a possibility to maintain and set up the web auditoriums and gives access to the following functionality:

- Applications – the module provides access to the applications sent by the student. It is possible to print an application and to change its status – moved on for further processing, approved, or disapproved.
- Inquiries/reports – a number of reports related to accounting the time spent by the users in the system.
- Reminder – the system provides the ability to set up automated messages to the users, when events such as birthdays, special holidays, unpaid fees, etc. occur.
- Target group messaging – the system provides the ability to send messages to predefined target groups of users – for instance football players, volleyball players, graduating students, international students, etc. Target groups are created dynamically by the administrator and each group is assigned a number of users.
- Virtual lecture halls – provides functionality for the creation and administration of virtual lecture halls.

5 Adaptive Electronic Textbook

The main objective of a good learning system is to provide efficient learning to the students, who may or may not have prior exposure to the subject content and may also be less experienced in reflecting their learning experiences due to limited prior academic instruction [Kinshuk, 1996]. Existing research has

shown that application of adaptation can provide better learning environment in electronic learning systems. [Oppermann, 1997].

[Edmonds, 1987] described five areas the system can take into account while considering adaptation: user errors, user characteristics, user performance, user goals, and the information environment. According to [Kirschner, 2004], an adaptable e-learning system is an interactive system, which personalizes and adapts learning content, pedagogic models and interactions between its users in order to satisfy users' requirements and preferences.

According to Brusilovsky [Brusilovsky, 1997], there are two adaptable elements in hypermedia e-learning systems – the content of the learning pages, and the hyperlinks between them. We implement both adaptation elements, and we customization, as described by Opperman, Rashev and Kinshuk [Oppermann, 1997]. In DisPeL, adaptation forms a unique learning flow for every learner, putting foci points on topics which present greater challenge.

A third level of adaptation is implemented to meet the contemporary media trends. During the last few years, mobile devices, such as smartphones and tablets, evolved and became a major tool for content consumption. While traditional personal computers keep their role as content creation instruments, content consumption on mobile devices is becoming increasingly popular. The myriad variations of mobile devices, and different form factor put serious difficulties in presenting content properly across devices. Several techniques, such as Windows Presentation Foundation (WPF) [Microsoft, 2013] and HTML Media Queries [W3C, 2012] have been developed to tackle this problem. We rely on the latter to achieve adaptability of e-learning content and optimal user experience on mobile devices.

Adaptation requires information about user actions, and analysis of these actions. We base the adaptation in DisPeL on continuous assessment of learners' performance.

5.1 Adaptability

As mentioned above, DisPeL achieves adaptability through:

- Continuous testing. At the end of every chapter of the learning content, the learner is put to a test on the covered materials. The system assesses the answers and presents the learner with a summary of identified lapses in his knowledge. Then, the learner can quickly navigate to the related part of the content to improve his knowledge on these areas. A unique learning flow through the material is created for every learner.
- Personalization: learners can personalize the learning content. Personalization elements are private for learners, meaning these notes and highlights are visible only to the learner who created them. This enhances the personal experience for every learner. Personalization includes:
 - Add notes. Notes are free textual content which can be embedded into the e-learning content. Within the e-learning content, notes are indicated with small icons. Clicking on an icon will open a popup window with the note, where the user can make changes, or delete the note.
 - Emphasize content. Emphasis enables learners to put a visual mark on some part of the text, which can draw their visual attention quickly next time they are processing the text. Emphasis is achieved with two tools: highlight and underline.
 - Customize presentation of text. People's successful perception of written text can be affected by the text size, contrast, line spacing, and font. Therefore the SYSTEM enables users change the font, base size of the font, line spacing, and background and foreground colors.
- Adaptable presentation. The system detects the capabilities and form-factor of the presentation device using HTML Media Queries[W3C, 2012], and then adapts the content to achieve optimum experience across various devices.

5.2 E-Books

DisPeL defines e-book as unity of e-learning hypermedia content which targets certain learning subject and testing questions on the content. Every e-book has:

- Authors.
- Title.
- Edition.
- Chapters, including tests.
- Final test for self-assessment.

E-book content is organized in chapters. Every chapter has:

- Title.
- Chapter content. The chapter content can contain: formatted text, images, multimedia – embedded or streaming video and audio, and links to external sources.
- Test at the end of the chapter. At the end of every chapter, learners are subjected to a test on the learning content so far. Successful passing of the test is required to unlock the next chapter of the text-book.

5.3 Services

The following services are available to tutors:

- View and manage learning content.
- Author learning content.
- View current learning sessions.
- View students.
- Get reports for students' progress.

The following services are available to learners:

- View active e-books.
- Access learning content.
- Take tests and easily return to challenging learning content.
- Take self-assessment tests.
- Create, modify and delete personal notes.
- Create or remove emphasis.
- Personalize the presentation of the learning content.

5.3.1 E-learning Content Management Module (ECM)

This module is responsible for authoring of adaptable e-learning content. It implements the business logic for the functionality for tutors. ECM provides the following services:

1. Create new e-books.
2. Edit e-book's general data: authors, edition, summary, keywords, and discipline.
3. Create lessons.
4. Author lessons content.
5. Activate e-books. Once an e-book is active, it becomes read-only, and its content cannot be further modified. It also becomes available for learning sessions, and can be accessed by learners.
6. Obsolete e-books. E-books can be marked as "obsolete". Obsolete e-books cannot be used in learning courses, and become inaccessible to new learners. Learners, who have studied obsolete e-books, can still access them along with their private personalization data.
7. Create new editions of existing e-books. This feature enables tutors copy and existing e-book and start making improvements on it.

5.3.2 E-learning Session Module (ESM)

ESM is responsible for providing learning content, and service learning content adaptation and personalization. It implements the business logic for the functionality for learners.

When a user logs in, ESM retrieves all active courses and e-books for the user. Then the user can select an e-book to ready. ESM automatically positions the user to the last lesson opened by the user.

ESM generates the learning content dynamically by injecting personalization data into the current lesson. When a lesson is loaded, ESM loads all the personalization data associated with the current lesson and the current user. Then, ESM injects the appropriate HTML5 markup into the original text, and sends the result to the browser for rendering.

For example, the original content is: “But there are 10 policies that need to be included in every network-security policy, no matter the company's size, scope or focus”. User has highlighted “10 policies”. In this example ESM would produce:

But there are 10 policies that need to be included in every network-security policy, no matter the company's size, scope or focus.

At the end of every lesson, ESM loads the test for the lesson, and switches from reading into test assessment mode. The user can navigate through testing questions, give and correct the answers given.

5.3.3 E-learning Tracking Module (ETM)

ETM runs along with EMS. For every e-book and lesson, EMT records:

- The time spent on every lesson.
- The total time spent on the e-book.
- The progress of the learner.
- The performance of the learner on tests at lessons end.

5.4 Content Persistence

Every e-book is structured of ordered lessons. Every lesson has a title, and content. Lessons content is stored in a blob field as binary content, which is serialized text in HTML 5 format and encoded in UTF-8.

Personalization data – emphasis and notes, are stored in a separate table as JSON documents. The JSON document actually contains HTML5 markup with the personalization data and indices with the region within the learning content, where the personalization data should be applied.

Example of personalization note:

According to Raymond Chen, software security is irrelevant if the attacker gains physical access to hardware.

Example of emphasis:

{“EmphasisType”:”Highlight”, “Start”:5100,”End”:5152}

6 Electronic Testing and Assessment

Testing examination is one of the most popular and well-developed assessment instruments in higher education [Brusilovsky, 1999]. The classic test is a sequence of precisely defined questions, with each question suggesting a simple answer, which can be easily checked and assessed as correct, incorrect or partially correct (for example, incomplete).

Questions are often split in types, according to the expected answer:

- Classic type of question – with a “yes/no” answer.
- Multiple-choice question – one answer (MC/SA, Multiple-Choice/Single-Answer).
- Multiple-choice question – more than one correct answer (MC/MA, Multiple-Choice/Multiple-Answer).
- Free-type questions- with the answer being a number or a text.

- Others.

Most of the existing Web-based systems for testing and assessment provide technologies and tools for creation, submission and assessment of questions of the first three types [Gushev, 2002]. A certain number of systems process all types of questions [Ueno, 2001].

However, most of the latter do not provide a solution to the problem for dynamic creation of questions, which forces the development of a large set of test versions, in order to prevent the test from being learned by heart.

The Distributed eTesting Cluster – DeTC features all the standard tools for real testing examination and assessment that exist in other testing systems. In addition, DeTC offers a set of unique features and tools, which allow generation and assessment of multitude of unique testing questions while minimizing the manual work involved preparing the questions:

- Dynamic questions. A dynamic question is a question template with variables. Unique testing questions are given generating random values for the variables in the question. This does not increase the number of the preliminary created questions, and decreases the size of the database with tests [Rahneva, 2003; Rahneva, 2004a].
- Group testing examination and assessment. This tool provides a way to examine a group of learners in a way that prevents cheating. The tool is described in [Rahneva, 2008b; Golev, 2009].
- Testing questions in accounting. Accounting questions are specific because of the specific format of accounting booking operations, where there are multiple correct forms of the answer [Rahnev, 2008b]. Accounting questions can be dynamic as well.
- Tool for authoring and automatic generation of circuitries and drafts for testing examination in Electronics, Physics, Chemistry, etc. [Rahneva, 2005].
- Tool for generating and assessment of dynamic questions in SQL [Rahneva, 2008a].

The testing component of DisPeL implements the testing methodologies of DeTC with contemporary technologies and into the cloud.

7 Technologies

The platform is developed using Microsoft .NET Framework, version 4. Technologies used include ADO.NET, Entity Framework, Windows Communication Foundation (WCF), and ASP.NET.

Commonly, every component includes storage, a business layer, and presentation layer.

Storage is persisted in Microsoft SQL Server relational database system. Every cloud task can use its own database, or share a database with the other tasks. When separate databases are used, common data is replicated across cloud tasks on demand.

Business logic is implemented and exposed by SOAP and RESTful web services. The standard protocols enable third-party systems to use the services of the platform.

Web-services which return JSON objects are implemented as ASP.NET web-methods [Esposito, 2007]. The presentation layer with its web pages calls the web methods of the appropriate module in AJAX calls, and then processes the returned JSON object.

The business logic modules interact with the storage via ADO.NET and Entity Framework, which enable use of LINQ-to-Entities technology.

The presentation layer is a dynamic HTML5\CSS3 application, developed with ASP.NET. It makes heavy use of JavaScript and AJAX technologies. Every ASP.NET web page contains a JavaScript View Model which conducts the behavior of the page. We make extensive use of web methods, which return response in JSON format.

The presentation layer uses CSS Media Queries to detect the capabilities of the rendering device, and adjusts the UI elements and functionality accordingly. For example, for mobile phones, where the screen has low-form factor and resolution, the presentation layer would first increase the font size to improve readability of the text; next, it will disable highlighting, because it is not a feature in a mobile browser.

8 Implementation

DisPeL is successfully deployed and implemented in several universities in Bulgaria:

- Faculty of Mathematics and Informatics, Plovdiv University “Paisii Hilendarski”, Bulgaria.
- Plovdiv University, branch Smolyan, Bulgaria.
- Academy of Music, Dance and Visual Arts, Plovdiv, Bulgaria.
- National Sports Academy, Sofia, Bulgaria.
- Etc.

The unmatched level of automation of the administration of the learning process and its integration with the electronic learning enables creating many new electronic services for learners and tutors in these universities.

9 Next Version

The next version of DisPeL is targeted towards mobile services and learning via mobile interaction. Native mobile applications will be developed for the popular platforms: iOS (iPhone and iPad), Android, Windows Phone and Windows 8. We chose native applications due to the limitations of HTML5 which does not allow optimal utilization of the underlying hardware. Further, HTML5 makes it more difficult to achieve user experience, compatible with the appropriate software platform.

The other new vector of development is towards creation of education via games. We will build upon an existing platform for mobile games [Pavlov, 2012a]. DisPeL will feature a platform for single and multi-layer mobile games. Educational games will open DisPeL towards younger learners and learners with special educational needs. Games can also be included in the higher education.

The next version of DisPeL is currently under development.

10 Conclusion

The Distributed Platform for Electronic Learning DisPeL is an evolutionary development to the Distributed Electronic Testing Cluster – DeTC in three particular aspects. First, DisPeL adds automation of the administration of the learning process, and provides full integration between the administration and learning on both process and service levels. Second, DisPeL employs a model for adaptive electronic learning content to enhance the quality of the electronic learning process. Third, DisPeL is architected as software as a service on the cloud.

DisPeL is successfully implemented in several universities in Bulgaria. It is also being targeted towards electronic education for business companies who seek to improve the qualification of their staff.

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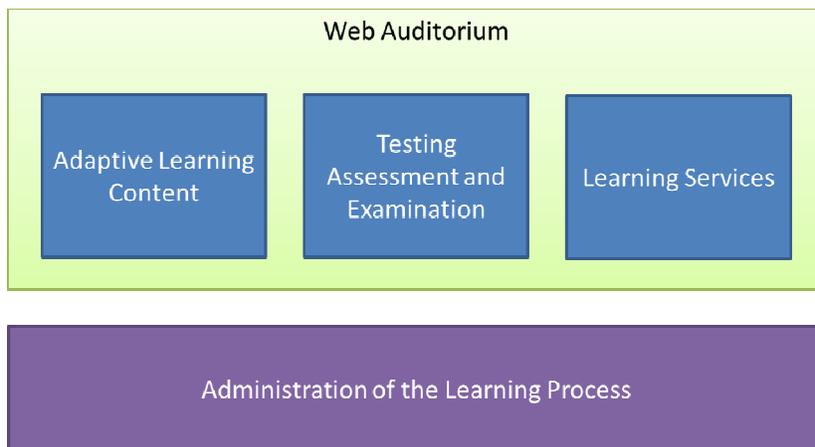


Figure 1. Model of DisPeL

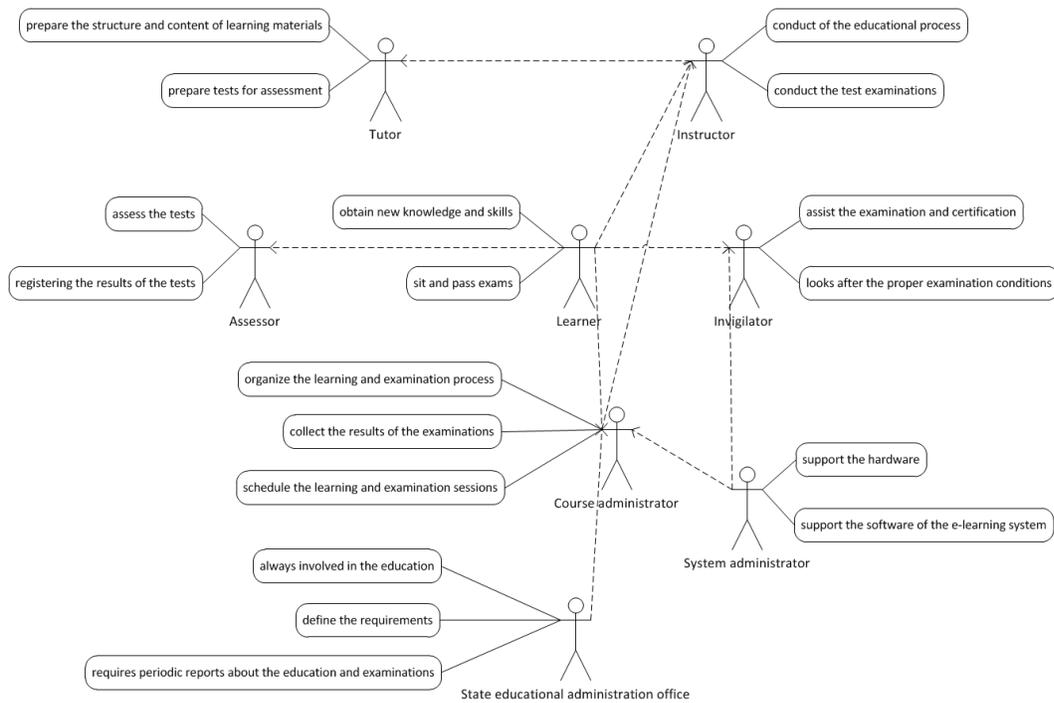


Figure 2. UML diagram of user roles and responsibilities