

DeLC Educational Portal

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Abstract: *A service- and agent-oriented portal architecture is presented in the paper. A prototype of the architecture has been implemented for e-Learning application. Various electronic services delivered by the education portal are described as well. The teaching material according to SCORM 2004 can be prepared with the help of two tools presented in the paper. The manner of work with the portal is presented in brief.*

Keywords: *e-Learning, educational portals, agent-and-service-oriented architectures, electronic services, DeLC.*

1. Introduction

In recent years the interest towards electronic education has been growing stronger. As a result of that many universities have developed and implemented their own systems for electronic and long-distance education. Alternatively, many of the large IT corporations (e.g., Microsoft Class Server [1], IBM [2] and HP [3]) have developed commercial systems whose price is often very costly. On the other hand, there are different open-source systems available on the market (the best known is Moodle [4]). A number of standards for electronic and life-long learning are also emerging. There are quite a few organizations working to develop specifications and standards such as IMS, ADL, ARIADNE, IEEE, ISO, etc., to provide a framework for e-Learning architectures, to facilitate inter-operability, content packaging, content management, Learning Object Meta data, course sequencing and many more. A significant role is played by the Sharable Content Object Reference Model 2004 (SCORM 2004) standard [5]. Similar tendencies are also underway in

Bulgarian universities and schools. Most of these institutions offer different opportunities for aiding electronic education. Some of them adapt Microsoft's Class Server, others build their own architectural models and educational platforms, such as Sofia University's ARCADE [6], Varna Free University's e-School [7], National Defence Academy's Flame [8]. A good environment for electronic education in the secondary school is the environment presented in [9].

DeLC (Distributed e-Learning Center) is one of the projects aiming to develop an environment that supports electronic and long-distance forms of education. The center's main ideas are laid out in a number of publications [10, 11]. Why, despite the presence of so many systems, we find it necessary to dwell on this subject? DeLC is mainly a scientific research project for developing new context-oriented and adaptive architectures. An important secondary goal of this project is the development and experimenting with prototypes of such architectures in a certain area of application (the electronic education). To achieve this goal we develop service- and agent-oriented environment for delivery of teaching materials and educational electronic services [12-14].

Furthermore, in many of the existing systems for electronic education, the interaction with the teachers is somewhat static – it is achieved mainly through pre-defined templates for choosing information resources. The information resources are the electronic equivalent of the traditional students' books. Some of the existing systems use visualization and animation for improving the tools of presenting teaching materials. In our project we would like to research how such architectures can promote the development of electronic educational environments which support an interactive, proactive and personalized process of education and stimulate the students' creative and innovative thinking and performance.

Interactivity expands all these forms and provides a dialogue between the system and the users, where it is possible to place and track the execution of individual tasks, as well as the interaction with personal assistants, etc. Moreover, interactivity allows the students to experiment with concepts, theoretical models and approaches while receiving a feedback and a response from the system. An excellent example for using visualization and interactivity in the teaching process of Theoretical Informatics is the device JFLAP [15].

Through personalization we aim to assist the students as efficiently as possible in accordance with their individual qualities, preferences and initial knowledge. Thus, for example, the teaching resources have a weblike structure and they are presented in portions by means of specialized software (Learning Management System), depending on the particular student's behavior and progress during the teaching process.

The system's proactivity is aimed at making it more user-friendly. Thus, for example, in certain cases the portal may decide that something, which is happening, is of interest to the particular user, so it may initiate a dialogue or execute certain actions on their behalf.

In this publication we present the current state of the educational portal that is being developed within the framework of the project, the realization of which implements the afore-mentioned ideas.

2. Distributed e-Learning center

The Distributed e-Learning center (DeLC) infrastructure has been introduced in various papers [16, 17]. In this section the logical structure of the center is described only briefly. DeLC is presented as a network, which consists of separate nodes, called e-Learning (eLNs). The nodes model real units (laboratories, departments, faculties, colleges, and universities), which offer a complete or partial educational cycle. The functionality of an eLN is presented as a set of e-Services. The configuration of the network edges is such as to enable the access, incorporation, use and integration of e-Services located on different eLNs.

Electronic services are provided by physically separated servers or by a network of servers (e-Learning Nodes, eLNs), which may dynamically connect to each other and form educational clusters (Fig. 1). Access to services can be either fixed or mobile.

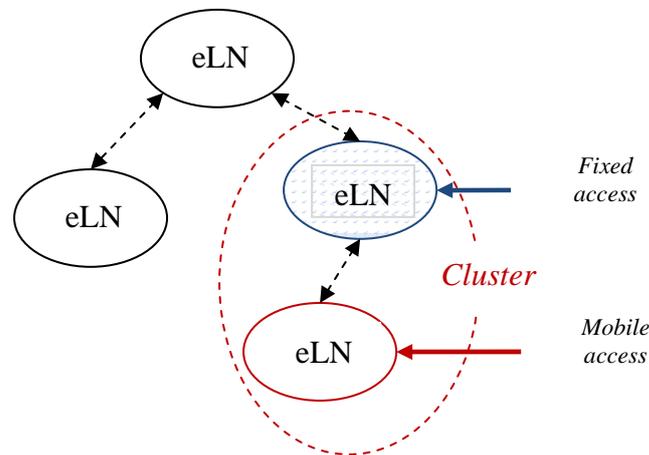


Fig. 1. The DeLC network model

Remote e-Service activation and integration is possible only by means of previously defined virtual structures. In the network model we can easily create new structures, re-organize or remove existing structures (the re-organization is done on a virtual level, it does not affect the real organization). For example, the re-organization of an existing virtual structure can be made not by removing a node but by denying the access to the corresponding e-Services offered by it. The re-organization does not disturb the function of other nodes (as nodes are autonomous self-sufficient educational units providing one or more integral educational services).

3. Portal architecture

For the realization of the educational portal, which is interactive, proactive and capable of delivering customized electronic services and electronic content, we apply the following architecture solutions:

- Development of a multi-level service- and agent-oriented architecture through portlet technology;
- Presentation and processing of electronic content in accordance with the standard SCORM 2004;
- Usage of different types of information objects with a clear separation of their content (data) from the description (metadata), including a detailed classification scheme for potential users of the educational portal;
- Usage of personal assistants.

3.1. Service-based and agent-based multi-layered architecture

The educational portal is developed as a Web application with a multi-layer architecture (Fig. 2). For the development of the architecture we use service-oriented design principles of the portal framework Liferay [18]. The Enterprise Service Bus (ESB) is a central connection manager that allows applications and services to be added quickly to the infrastructure of an enterprise. When an application needs to be replaced, it can be easily disconnected from the bus at a single point.

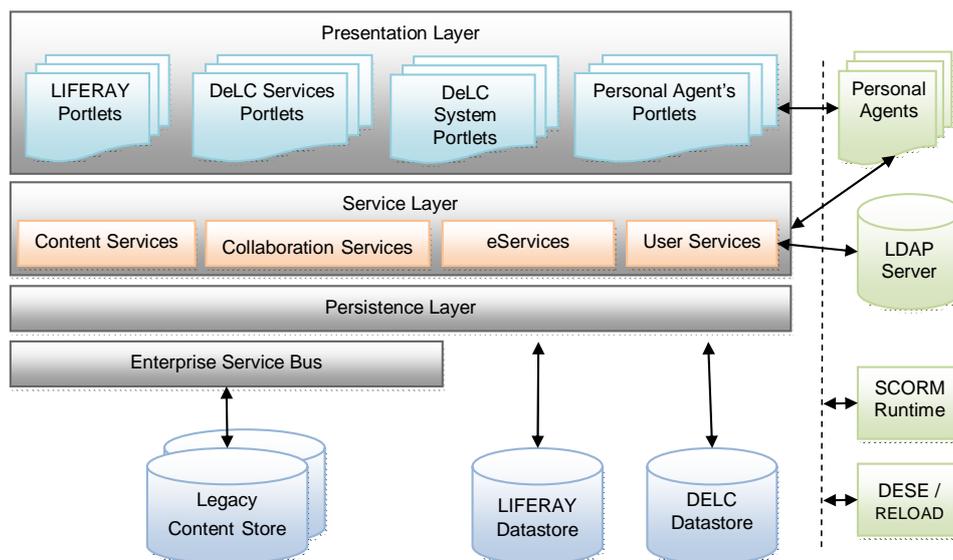


Fig. 2. Portal architecture

The main elements used in the architecture are portlets. Portlets are flexible and configurable building blocks for the design of portal applications. Portlets are used to build more complex components, included in the architecture of the portal, e.g., Electronic Services.

Presentation Layer is the outer layer that ensures user interaction by providing access to the entire system from one point. It allows personal settings of the client user interface. This layer is composed of a set of portlets that are organized into several main groups:

- *Liferay Portlets* are a group of portlets offered by the portal itself. They include:
 - CMS Portlets – for the development of an integrated content management system (CMS);
 - Collaboration Portlets – with their help are realized asynchronous communications between users (forums, off-line consultation) and synchronous communications (on-line consultations, chat-rooms);
 - Portal Admin Portlets – for the management and administration of the portal.
- *DeLC Services Portlets* are DeLC portlets with a specific functionality. These include:
 - portlets designed to work with the SCORM content by both the teacher and the student:
 - Portlets for teachers – with their help, teachers can support SCORM-based e-content (lectures, courses) and provide access rights to that content;
 - Portlets for students – portlets for accessing the SCORM content;
 - portlets designed to work with the test system of the portal:
 - for the teachers – portlets for managing tests and questions of different types, evaluation of conducted tests and analysis and statistics of results;
 - for the students – portlets for testing and review.
- *DeLC System Portlets* are a group of portlets for the administration of specific DeLC objects:
 - users – students, teachers, members with special roles;
 - specialties, disciplines;
 - curricula and schedules.
- *Personal Agent's Portlets* are accepted by a user as an interface to the personal assistants.

Service Layer consists of the system's services.

- Content and Collaboration Services are services that are provided by the portal framework and are mainly used by Liferay Portlets.
- e-Services are services related to the specifics of DeLC – electronic content (SCORM), tests and specific services for teachers and students.
- User Services are services related to management of users, authentication and authorization facilities. The architecture of the portal allows user authentication to be carried out by different mechanisms – Yale CAS, JAAS, LDAP, Netegrity, Microsoft Exchange and others.

Persistence Layer takes care of the connection of modules with storage systems (such as DBMS, file servers, etc.).

3.2. SCORM-based e-Content

For the maintenance of the desired interactivity, proactivity and personalization, it is essential to choose an appropriate format and structuring scheme that allows flexible structuring of the content so that:

- atomic building blocks can be identified;
- complex structures of the content should be built under certain rules from the simpler ones;
- different types of knowledge, such as problem-oriented or educational knowledge, as well as information on participants in the educational process, should be presented clearly and separately.

One possible representation, satisfying these requirements, is the standard SCORM 2004. The reference model of SCORM is a set of inter-related technical standards, specifications and guidelines developed to meet the highest requirements for learning content and systems governing the content. In practice, SCORM uses context-independent learning objects SCOs (Sharable Content Objects), which are built from simple building blocks, called Assets. To describe the characteristics of SCOs, we use Metadata. The training resources created are stored in a special online store called Content Repository. The SCORM model includes:

- Content Aggregation Model (CAM), which defines the components of the SCORM data model, how these components can be grouped in a comprehensive package and shared between different systems. In this model there are multiple meta-data elements that provide identification, as well as storing, finding and using the information objects more quickly and easily;
- Run Time Environment (RTE) can be considered as a set of requirements for LMS to manage the run-time environment, in which learning resides. LMS takes care to ensure the proper sequence of actions performed by the student, depending on their behavior and the current training scenario;
- Sequencing and Navigation (SN) defines the methods for possible behavior through a sequence of discrete actions. This model is established on the IMS SS-specification, based on two fundamental concepts – learning activities and learning objects. The model describes the sequence of actions in the learning process, depending on the occurring events and behavioral responses of students through a series of rules under which LMS transmits the initiative between the training objects.

DeLC uses the SCORM Runtime Engine as an *external system* for interpretation and visualization of the SCORM content. The generation of this content is done by DESE environment or the Reload editor. The integration of both DeLC external systems takes place on two levels. The first is the integration of a database level. At this level the relevant tables, that maintain information necessary for the SCORM RTE, are added to the model of the DeLC database. It also includes additional elements, related to granting the users rights of access to resources provided by SCORM RTE. Fig. 3 shows a sample model of the database that contains tables related to SCORM RTE.

On the second level the integration is carried out based on services provided by the SCORM machine and used by DeLC. This is done through portlets, serving the management of electronic lectures. Fig. 4 shows the architecture of the SCORM machine and the integration of services in DeLC.

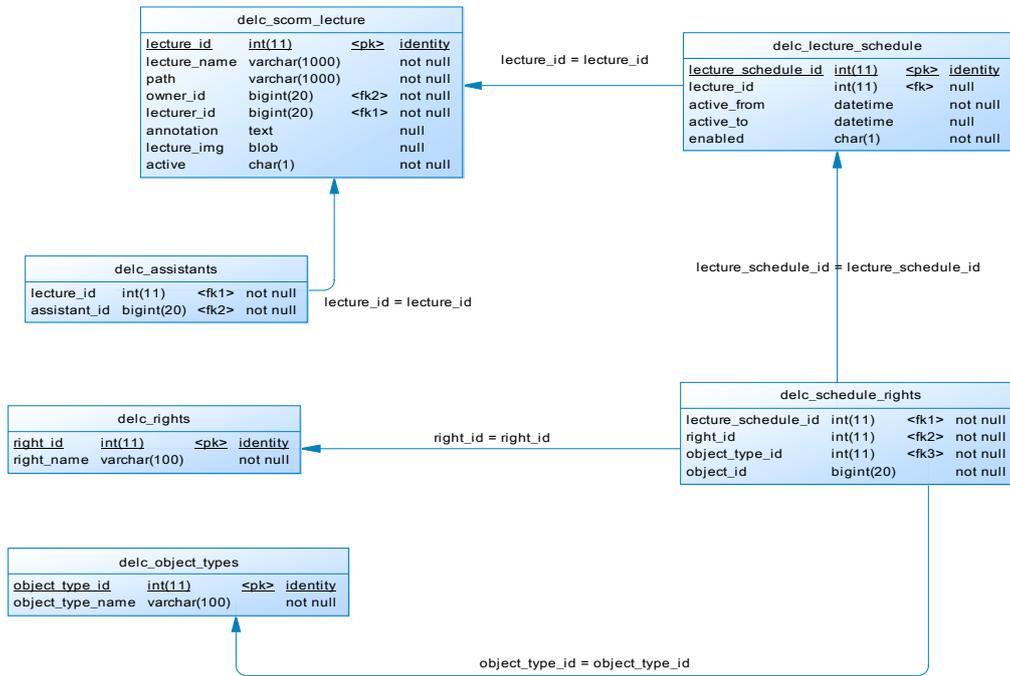


Fig. 3. Structure of the database

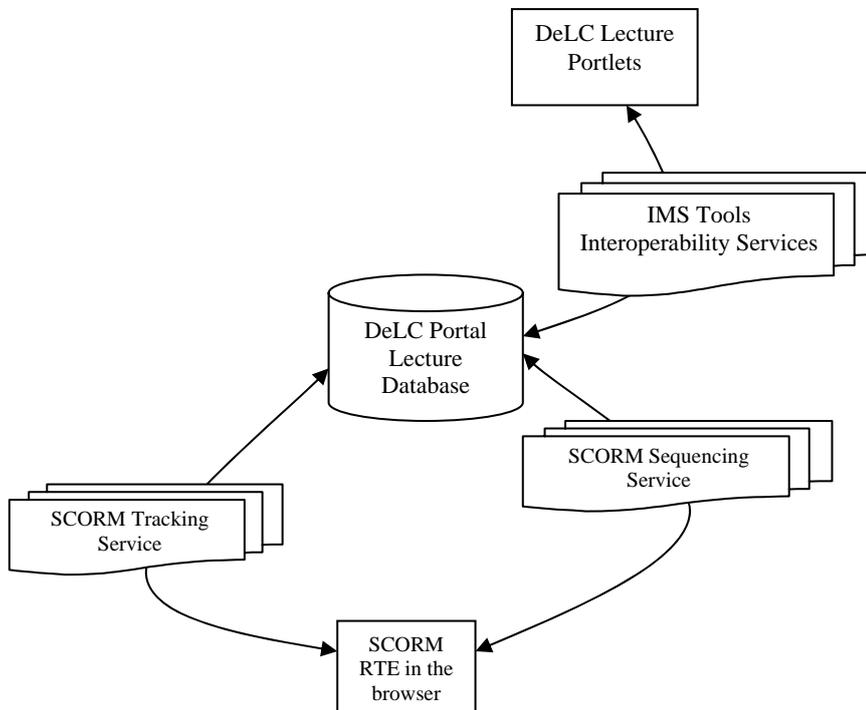


Fig. 4. Service level integration in DeLC

3.3. Information objects

In order to support an interactive and personalized delivery of services and content in the portal a uniform approach is designed for the representation and processing of various types of information objects. For each type of an object we have established a classification scheme and a profile type. Thus, each object can be uniquely identified according to its location in the classification scheme and its individual profile. Each profile is presented as a set of ordered pairs $P = \{(a_i, v_i) \mid a_i - \text{attribute}, v_i - \text{value}\}$, $i = 1, \dots, n$, that is open and can be extended with new attributes if necessary.

The following main types of information objects are supported in the portal:

- Users;
- Electronic content;
- Services;
- Events.

As an example we will present a more detailed classification scheme for potential users (Fig. 5.). Using the capabilities of the portal framework LifeRay, this scheme includes the following types of objects:

- Users – Users can be collected in multiple ways where they can be members of organization hierarchies, of arbitrary user groups, of communities, which draw together common interests, etc. They can have roles, which describe their functions in the system.
- User Groups – User Groups are simple, arbitrary collections of users, created by administrators. They can be members of communities or roles.

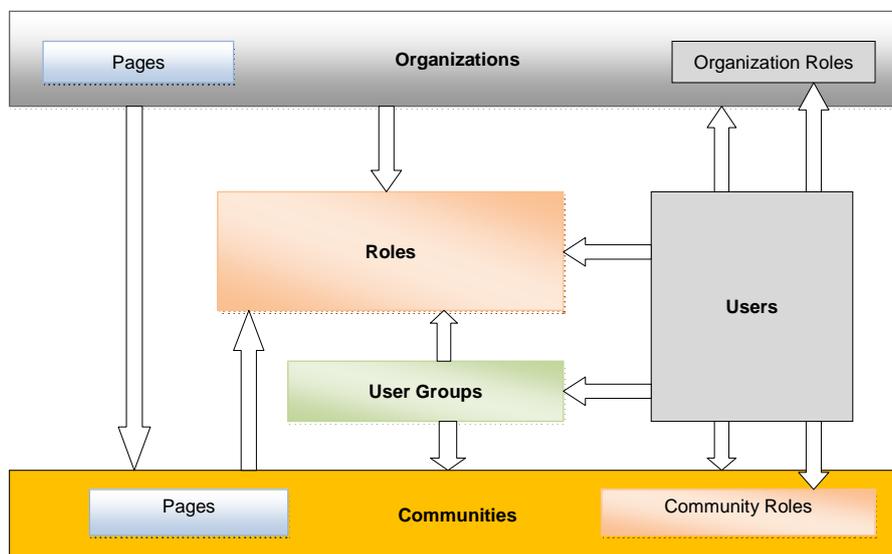


Fig. 5. Classification scheme of the users

- Roles – Roles are used to define permissions across their scope: across the portal, across an organization, or across a community. Users, User Groups, Communities, or Organizations can be members of a role.

- Organizations – Organizations are hierarchical collections of Users. There is also a special type of Organization called a location, which can define where users are specifically located.

- Communities – Communities are collections of Users who have a common interest. There are three types of Communities: Open, Restricted, and Hidden.

Users can be collected into User Groups and Users can belong to Organizations. Organizations can be grouped into hierarchies (such as Home Office → Regional Office → Satellite Office). Users, Groups, and Organizations can belong to Communities that have a common interest.

3.4. Personal assistants

The architecture of the portal is provided for inclusion of personal assistants who will assist users in working with the portal. Thus each user will have a personal assistant who can:

- deliver personalized electronic services and electronic content depending on the profile;

- carry out actions on behalf of the user;

- assist the user in working with the portal (intelligent help).

Once a user is registered in the portal, they will be able to configure their own personal assistant. Personal agents will operate on the portal server and will be constantly available. We plan to develop two types of personal assistants – for students and for teachers.

The use of personal assistants is essential for the proactivity in a portal architecture. Moreover, agents will improve the interactivity and personal delivery of electronic services and electronic content.

4. Electronic services

In accordance with the service-oriented architecture of the portal, its functionality, intended for operation by users, is offered as separate electronic services. For flexible and efficient management, we have developed a classification of the provided services.

The services are divided into three major groups by their functionality:

- Services for preparation, organization and planning of the teaching process – this group consists of services for providing information about the educational process and the creation of curricula and curriculum schedules;

- Services, directly supporting the learning process – this group consists of services, such as e-Lectures, e-Test, and electronic consultation;

- Services for recording and documentation of the teaching process – these services support the automatic generation of documents required for recording of

the learning process, e.g., examination protocols, an electronic student book, a teacher's electronic diary, and archives.

According to their purpose, services are divided into three categories:

- Services for students – they are intended for training and supervision of trainees. These include services for accessing and reading pre-prepared electronic lectures (based on an intelligent search module), for sitting for tests (mandatory or optional) in studied disciplines, for consultations with teachers, reviews of a student's book, as well as some additional services not directly related to teaching, such as an intelligent personal calendar;

- Services for teachers – they are intended for the teaching staff and allow the addition of lectures in the digital library, creating a library of test questions, creating, reviewing and evaluating tests and an intelligent personal calendar;

- Services for administrators – they are intended for management, configuration and planning of the teaching process and for related users, rights and services. These include services for creation, activation and deactivation of users and roles, the addition and removal of services and rights of access, curriculum management, academic calendar, early warning systems and a calendar of events (e.g., upcoming exams, sessions and important dates).

Moreover, services can be classified depending on the degree of compliance with various e-Learning standard, such as SCORM 2004 or ELF. The e-Learning Framework (eLF) [19] delivers a set of education service specifications. We differentiate between internal services (situated inside the portal) and external services (situated outside the portal, but whose results can be integrated into the portal).

For better perspicuity, the services included in this version of the portal are grouped in the following modules:

- e-Testing module;
- e-Lectures module;
- Planning & Control module;
- Documentation & Statistics module.

4.1. e-Testing module

Tests play an important role in the teaching process. They are the primary mechanism for verification and control of the knowledge of learners and the absorption of the lectures. As an important teaching tool, the electronic testing system is a key component of the portal. In order for the portal to be accessible to a larger group of users, each teacher can enrich the accessible repository of the test questions in their discipline. The module allows the conduct of individual electronic testing of students. Teachers prepare templates that the system uses to automatically generate individual tests (instances of the template) in real time (during the exam). Moreover, the module provides a service to support the evaluation of tests. Fig. 6. shows the UML use cases diagram of the e-Testing module.

4.1.1. Question and test pattern editing

The main goal of the testing module is to establish and maintain a database of questions. For each discipline there is maintained a separate database. Furthermore, the questions can be grouped by individual topics but within a thread – the degree of difficulty of the matter. As an information object each question consists of three parts:

- contents;
- a number of possible answers – depending on the type of the question there are one or more correct ones;
- profile of the question – metadata that characterizes it.

The profiles contain mainly the following information:

- ID of the question;
- membership – discipline and topic;
- type of question – the current version of the system supports different types of questions such as closed questions, which have one correct answer or more than one correct answers, and open questions, which can be long, short, or can consist of a short fixed text;
- degree of difficulty – depending on the degree of correct answers, there are given different numbers of points in the evaluation;
- language of the question;
- author.

The portal provides an editor of the questions, by which the teachers can create, edit, delete and search questions in the database.

In preparation for the final test of a group of students, teachers need to prepare only one test pattern. The pattern is a specification, from which the portal automatically generates individual tests in real time while ensuring the equality of students. The pattern includes:

- topics of an examining discipline to be included in the test;
- number of questions for each topic;
- type of questions;
- degree of difficulty.

Moreover, teachers also set profiles of test patterns that contain the following metadata:

- ID of the pattern;
- examination discipline;
- academic year, semester (trimester), date of creation;
- author;
- validity – the teacher can determine the time interval in which the test is available;
- access – tests can be locked with a password; this password is used by students to generate individual tests; having completed the test generation, the teacher can change the password and in this way the test becomes unavailable and it cannot be copied or sent over the network;
- duration of the test;

- activation of the test – tests can be activated in two ways: manually or automatically; the manual activation is done only by the teacher; the automatic activation is done when there occur any conditions, satisfying the validity of a test;
- evaluation scale – teachers can set correspondence between test scores and grades; this is used for an automatic evaluation of tests.

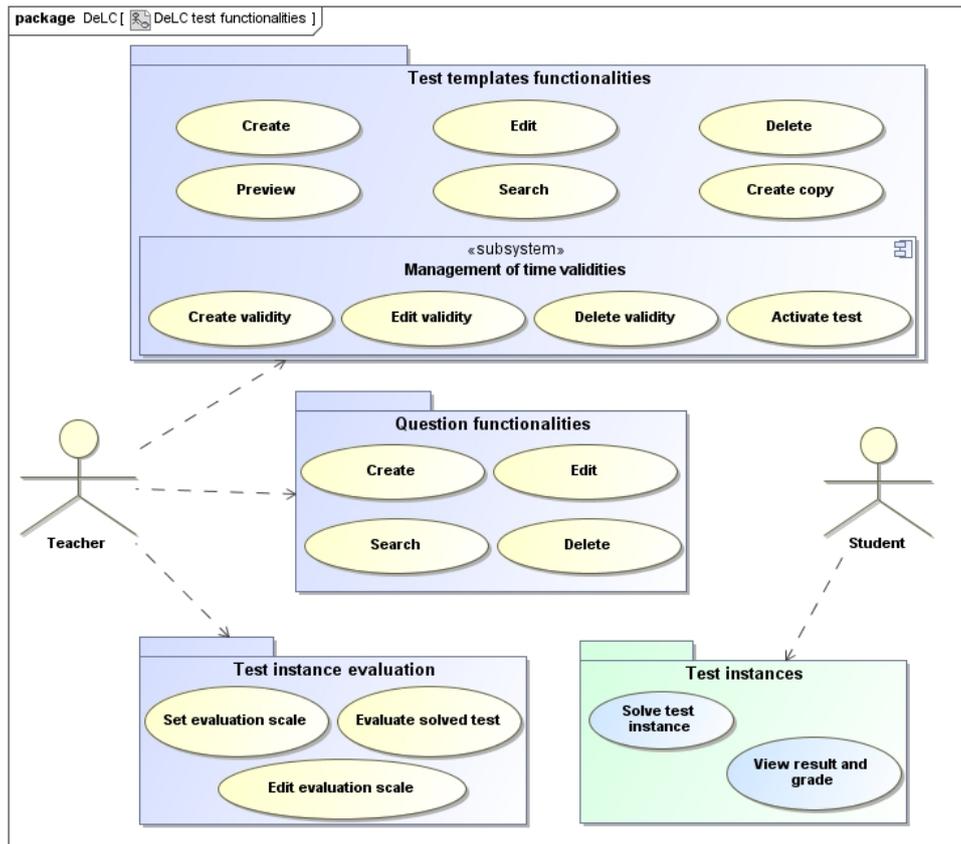


Fig. 6. Use-case diagram of the base functionality of a test system

During the automatic generation of individual tests, this module may take additional personalization. For example, in repetition of questions the order of the options or the presented alternative formulations of the answers may be modified. The model of personalization is realized more efficiently in large databases of questions from the examination subjects.

The portal provides an editor of tests, by which teachers can create new templates, copy and edit existing templates, and search and review the database.

4.1.2. Test conducting and evaluation

E-testing can be activated in two modes – self-assessment of students and conducting an examination. In the self-assessment mode the students can check their knowledge via tests, without any restrictions. Thus, for example, access can be

free, and the validity and test duration can be longer. In the examination mode tests are conducted in computer labs in the presence of assistants who determine the necessary restrictions. The test ends when the student is ready or the test duration expires – in that case the system automatically terminates the test and stores the results. Students can review their own, already assessed, tests.

The tests solved can be evaluated by teachers manually or through using the system. The portal can automatically evaluate questions of types that are different from the “open questions”. Partial evaluations of the system can be combined with evaluations of the open questions by teachers, and a final evaluation is stored in the database.

4.2. e-Lecture module

The creation of electronic content is performed by external services using the development environment Selbo 2 and editor Reload. The electronic content is imported into the portal to be presented to the students. The electronic content is offered in separate lectures, which are grouped into courses.

Selbo 2 is a development environment and an intelligent workplace for teachers, which aids them in creating interactive learning material. The Selbo 2 [20] environment is not monolithic, but rather a set of editors interconnected into a single user interface (Fig. 7). The editors, in turn, can be dynamically added, removed and replaced without modifying the rest of the system (a plug-in system). The editors themselves are components of the GUI. They are used for the actual editing of the various electronic resources. In general, the editors can be attributed to two groups. The first group contains editors of the standard formats, independent of a specific domain, such as the text editor and HTML editor. The second group contains specialized editors relevant to a specific domain (in this case “Software Engineering”), i.e., the UML editor, the editor of the source code, and others. In Selbo 2 some of the editors are implemented as intelligent components – a combination of visual interface component and a specially created intelligent agent.

The Reload Editor, designed for creating standard electronic content, compatible with SCORM 2004, is developed within the European project RELOAD [21]. For the purposes of our development we have created and maintained the Bulgarian version of the editor. The Reload editor (Fig. 6), is a tool for developing electronic content such as Web pages, images, animations, Java applets and more. Unlike Selbo 2, which is designed for an easy, quick and convenient creation of courses in a particular domain, the Reload editor enables fine control of the rules of sequencing and navigation, according to SCORM standard. The editor is used in many European universities. SCORM electronic packages can be provided for further processing (update, modification, integration with other components present in the environment, etc.) in the “workplace” of the teacher (Selbo 2) or directly integrated in the educational portal.

During the import the teachers can create annotations of the courses and determine the rights of access to the educational content. Annotations are an essential part of the mechanism for finding lectures, which are appropriate for or match students’ personal preferences and interests. Annotations are visible to all

students with access to the relevant course. The lecturers themselves define the access rights, which may be user roles, individual users, user groups, organizations, and communities. Moreover, teachers can set rules governing the period of access to the educational material.

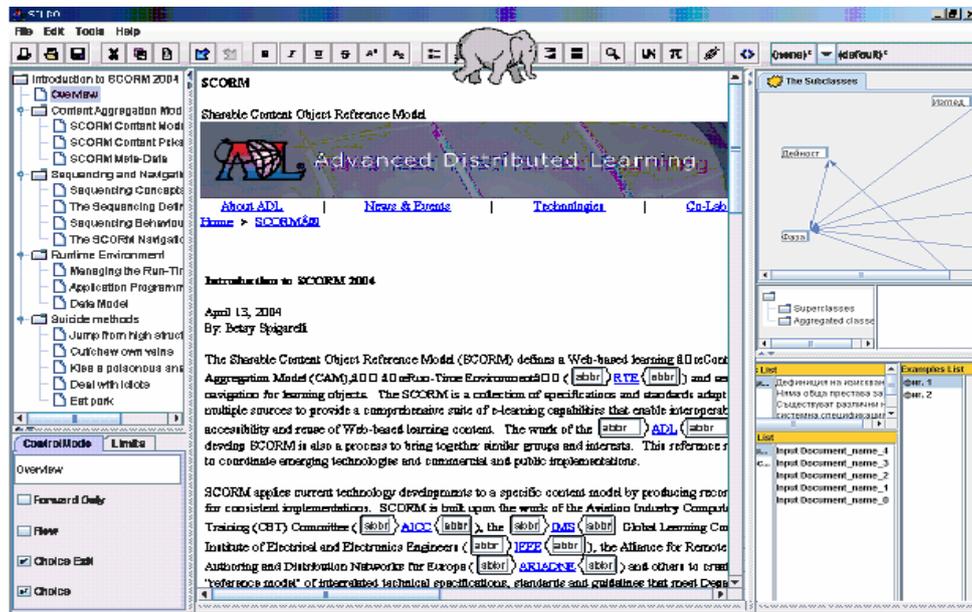


Fig. 7. The Selbo 2 environment

The students' access to the electronic content is determined according to the students' rights and roles. This service supports intelligent search of lectures, corresponding to the personal interests and preferences of the students. Information about this search is derived from the profiles of the users. The profiles are continually updated with each attended lecture or sitting for a test in a given discipline. Visualization of the electronic content is performed by the integrated SCORM engine.

4.3. Planning and control module

In this module there are services that support the planning and organization of the educational process. Planning is done in three distinct phases. The first phase is developing curricula that consist of a set of disciplines, each one of which is defined by its name, workload, number of credits, and annotation. Each curriculum can have a number of electives, which will be specified later in the curriculum scheduling. A curriculum is created for each specialty, supported in the portal. In the second phase, based on the curriculum, there is developed scheduling for the academic year. In this scheduling the curriculum is expanded with more information about individual teachers, disciplines, weekdays and times of conducting the training sessions, the numbers of classrooms, and dates of exams and sessions. In addition, in the schedule there can be added events of common interest, such as vacations and holidays. In the third phase each student and teacher

can prepare their own personal calendar. The personal calendar enables the users to add personal events, notes and comments. An important feature is that the personal calendar of an individual user synchronizes itself with the scheduling.

In accordance with our concept of proactivity, in this module a system for delivery of preventive information is developed. Its purpose is to inform the users of the system (students, teachers and administrators) about upcoming events that would be of interest to a particular user. For this purpose, the individual entries into personal calendars are defined as events. The system allows the users to indicate whether they are interested in a particular event or a type of events, so that the system would notify them (e.g., through e-mail or sms) some time before the event occurs. Thus, for example, the portal will remind the students that in a week time they will have an exam in a certain discipline. The users (students and teachers) can filter out what types of events they would like to keep in their individual calendar – personal events, events for their course, events for all the students or events, valid for the whole university.

Each event has its own characteristics, such as start time, end time, description, type, target group of users, and others. Based on these characteristics, each user can filter the set of scheduled events that they would like to see. When an event is being created or edited (whether by an administrator or a user), it may be flagged as being important for the target group. Then a request is made to the early warning module to notify all members of the target group some time before the event occurs. This request, along with the actual event, is stored in the database. Times for advance notification may be set manually for each event; additionally, different types of events have predefined times. For example, an event of the “exam” type can be configured, so that a predefined alert is two weeks before the date of the exam.

Each user can filter what types of notifications to receive for which events. Also, a user can change the date or completely disable a notification for a specific event. As part of their profile information, users can set their preferred method for receiving notifications.

The preventive information module is implemented through an agent (Fig. 8), whose role is to examine the database for an alert request. When it is time to process a notification request, the agent creates a list of all the members of the target group of the event and eventually removes users who do not wish to receive a notice of this event (and those who do not wish to receive notifications in general). The agent extracts information from the profile of each user about their preferred method for delivery of the notification (the methods may be several in number). Then the agent activates the communication protocols of the notice to each user. Some of the methods for notification are a message in the portal, an e-mail, SMS, and online communication systems such as ICQ, Skype and Jabber, and social networks, e.g., Facebook and Twitter.

The module also supports a service electronic student report. It is modeled after the classic student book, but provides richer capabilities. It allows students to examine their grades, the points from the tests, comments on grades, statistics and recommendations. In future the service will be progressively extended as the

student book becomes more interactive and proactive so that the final version will be an intelligent personal assistant of the student.

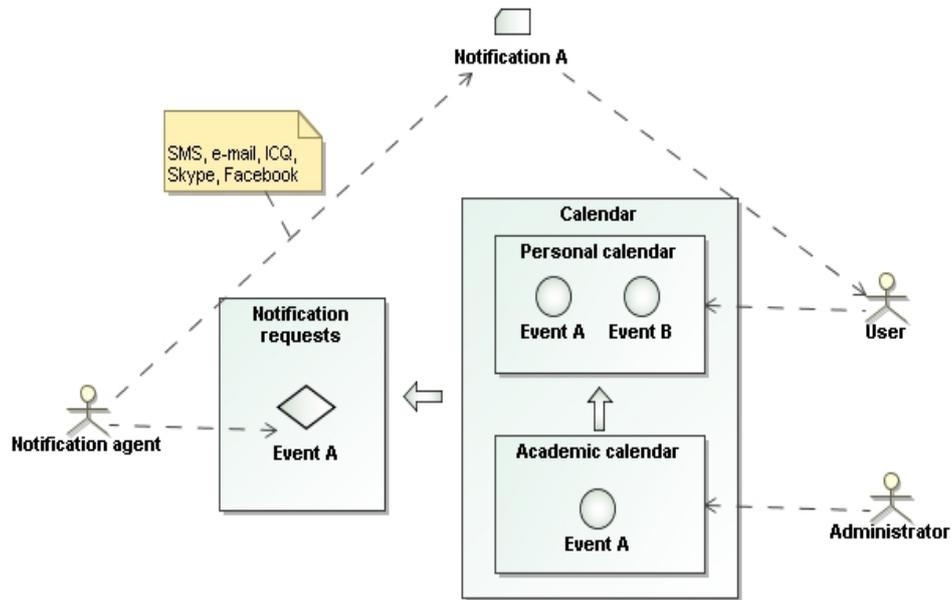


Fig. 8. The process of preventive information

4.4. Documentation and statistics module

Using the services, offered by this module, one can generate documents, needed for educational process protocolling. The results from the tests can:

- automatically be set in the individual students' records;
- used for the generation of examination protocols;
- used for the generation of various statistics;
- archived for future use.

5. Working with the portal

In this section the manner of work with the portal is presented in brief. The educational services can be accessed after a successful login (Fig. 9). There are two major roles for the user accounts, which give access to a completely different functionality – a teacher and a student.

The users with the role “teacher” have the ability to manage lectures and tests. The management of tests also includes a management of a set of questions. The portal has a rich set of tools for administering the tests and questions databases, such as the Test Management Console and Questions Library (Fig. 10). These powerful tools allow the teacher to create and edit tests and questions in an effective manner.

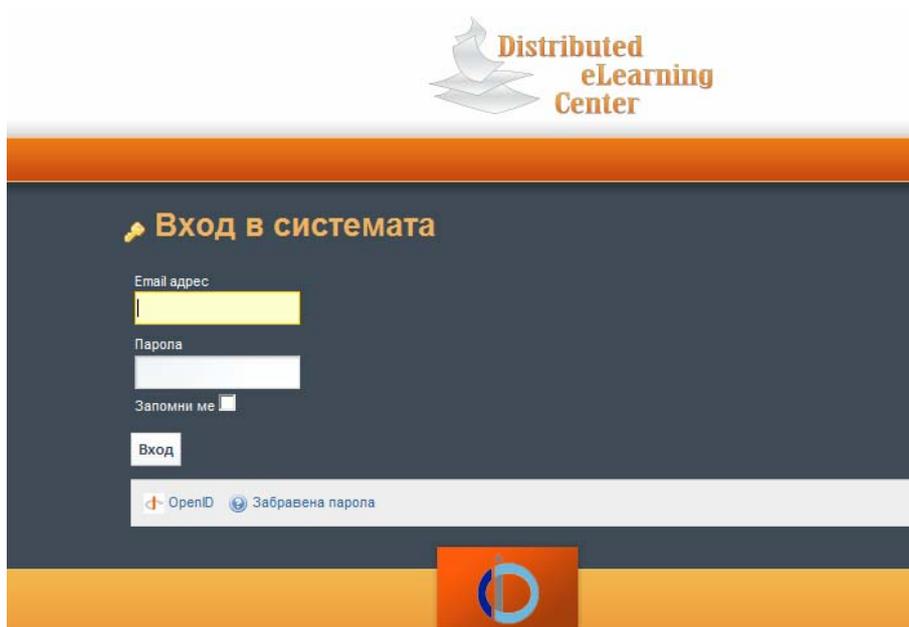


Fig. 9. Login screen

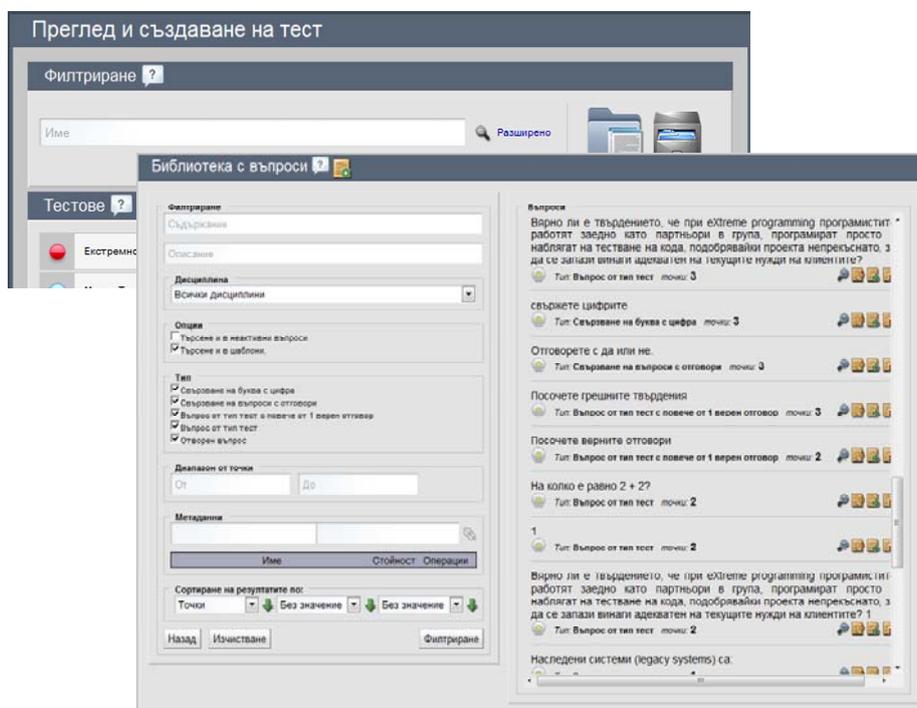


Fig. 10. The question library

The tests and questions entities have a lot of properties that can be set and this makes their usage very flexible. In order to create an appropriate test pattern, the teacher can also manage their status, the validity periods, and the rights for accessing them (Fig. 11).

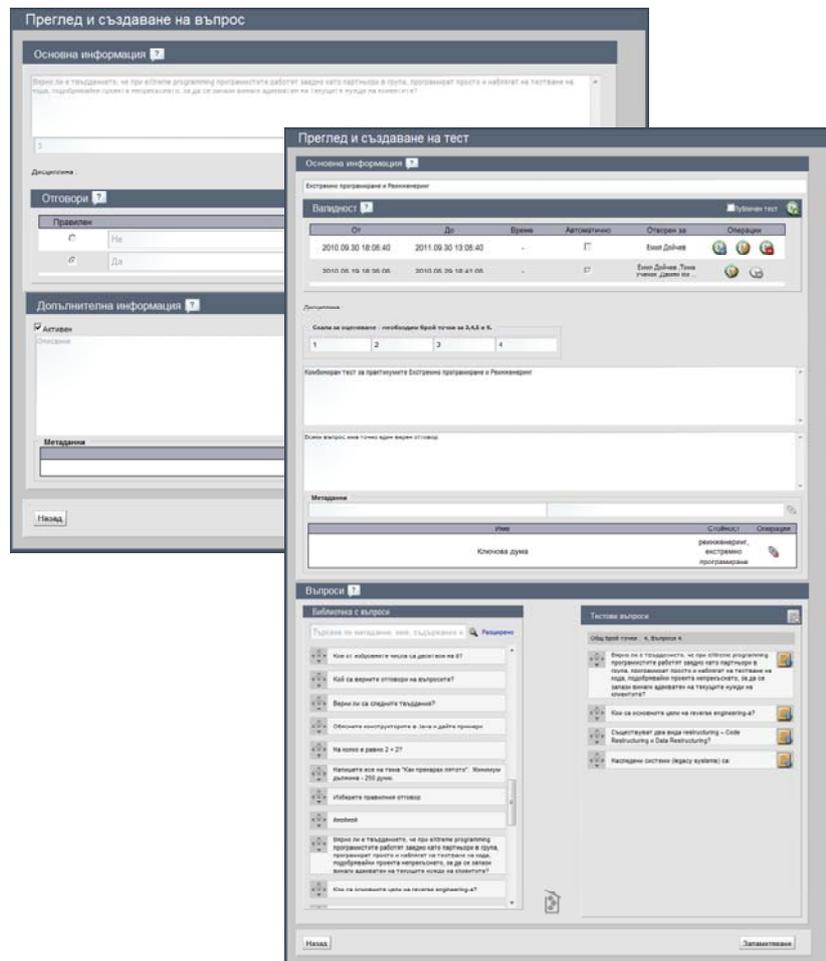


Fig. 11. Test pattern creation

During an exam, when a test becomes valid (according to the rules set by the teacher), the portal generates (from a test pattern) individual tests which can be accessed by users with the role “student” and which are intended to be examined with this test (Fig. 12). When a student is ready with the test examination, they immediately receive the result based on the questions, the answers to which can be evaluated automatically. If there are open questions, which need to be evaluated by the examiner, the student can check later to see their final result.

On the other hand, the teacher can check a student’s work in a convenient format, where they can easily see the student’s results. Also, the portal produces some useful statistics for the teacher, which show the student’s overall progress with the test (Fig. 13).

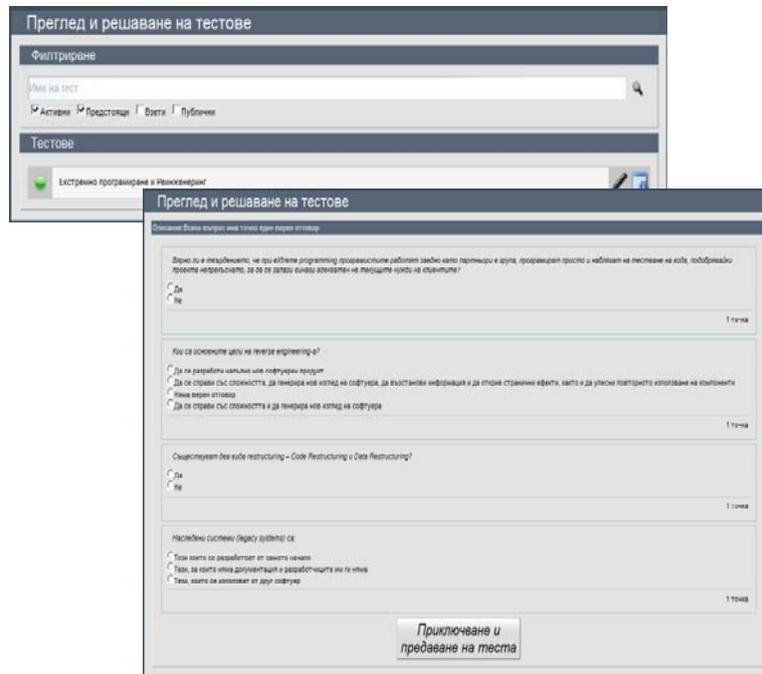


Fig. 12. Test completion

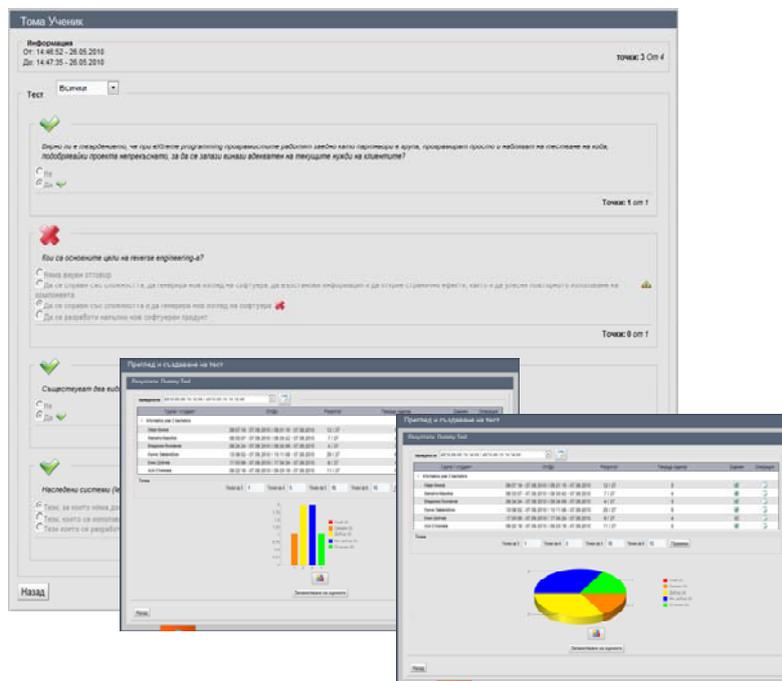


Fig. 13. Statistics generation

6. Conclusion

The first portal version is in the real testing phase. The implementation of the masters' program in Software Engineering at the Faculty of Mathematics and Informatics of the University of Plovdiv is supported by the educational services delivered by DeLC portal (<http://delc.fmi.uni-plovdiv.bg>). The next version is under development.

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