

Report on the infrastructure design and integration of the components

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Summary of deliverable

The purpose of this deliverable of E-GREEN JOBS project is to describe the main concepts of the ontology based electronic learning environment (Studio), highlighting the identification of those components which are necessary for the configuration of the platform. It helps better understanding the philosophy of the system background and gives detailed instructions for the further project activities and for the E-GREEN JOBS pilot implementation.

The document consists of 3 pillars. In the first section an overview about the learning system is given with definition of the basic concepts. In the second section system components, through their roles and functionalities are described. It also focuses on the learning infrastructure with describing the repositories and their main characteristics. The third section contains detailed information of the system architecture including the external accesses, authentication and design components.

This document is offered for those experts and involved partners who are working on the content development, building up the ontology model, and having administrator rights to the ontology based E-GREEN JOBS e-learning system.

1. Adaptivity in knowledge testing¹

1.1. Short overview of the Educational background

Adaptive knowledge testing is not a new invention. In the early 1970's, Lord, tried to apply adaptive techniques in test evaluation (*self-scoring flexilevel test*) (Haladyna, 1994). Later, in the 1980's information technology specialists have started improving the traditional paper and pencil based knowledge measurement methodologies. The basic principles of the Computerised Adaptive Testing (CAT) are given by Thiessen and Mislevy

- test can be taken anytime, no need of group-administered testing,
- there are no identical tests, as every test is tailored to the needs and capabilities of the test-taker,
- questions are presented on a computer screen,
- after the answer is confirmed there is no chance to change it,
- the examinee is not allowed to skip any of the questions and
- the questioning process is fully and dynamically controlled.

Modern adaptive test systems have to meet further criteria as well. To ensure individually tailored testing a valid testbank should be connected to the Testing system. In this repository all items should be administered individually and validated continuously (Bálya, 1997). Explicitly articulated levels of difficulties must be assigned to each item. The item-order, the result and the evaluation of tests, which were taken already, are stored in a single database.

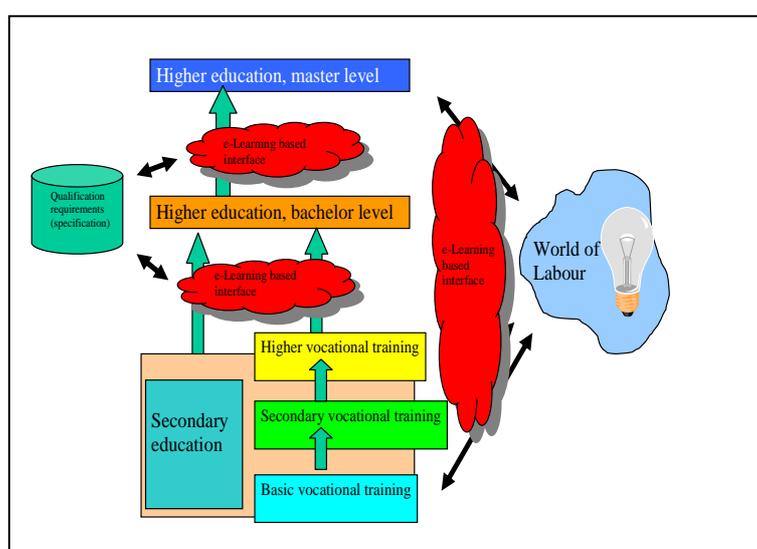
An interesting result of adaptive testing is the personalized e-Learning course delivery (Dagger, 2004). Once the test has been evaluated, the system offers courses, teaching materials based on measured knowledge of the student. (The meaning of measured

¹ Kismihók Gábor - Dr. Vas Réka Franciska (2006): *Ontology based Adaptive Examination System in E-Learning Environment*. 28th International Conference on Information Technology Interfaces. 2006. június 19-22., Cavtat/Dubrovnik, Croatia

knowledge will be explained later.) These systems can actively support the whole learning cycle. Connecting an adaptive e-Learning environment and an adaptive knowledge testing environment provides efficient support for individual learners. This support includes continuous developing and customizing of an active learning strategy for each student by the identification of problems in the prior learning and improving the quality of the learning experience.

1.2. The role of the knowledge testing in the course of Lifelong Learning

The development work meets with the requirements of handling transition between the different levels of the education system (VET, BSc, MSc, etc. levels). The goal is to introduce an interface, which can support customized qualification, based on the individual's previous qualifications, completed levels, corporate trainings and practical experiences, in case of entering a certain educational level. (See 1. Figure)



1. Figure: Educational levels

Two main groups of input are needed to build up this type of qualification program. On one hand the individual's knowledge and abilities must be measured, on the other hand a definition must be given about the prerequisites of the targeted qualification, which depends on the quality assurance and the accreditation system of the given education level, preferably in conformity with the EQF.

After testing the individual's knowledge, a customized supplementary training program can be allocated. A corresponding adaptive test provides help to the individual, who draws on this service. If the candidate passes the exercises and tests successfully, then the prerequisites for the certain qualification are fulfilled, and the student may enrol to the targeted level. As an additional benefit, some parts of this solution may be used for correcting the deficiencies of a certain curriculum during the qualification process, as an ad-hoc support of education.

The domain-specific prerequisites (e.g. accreditation) are defined by the ontology, so the knowledge test and the customization services are based on that. The system fulfils the criteria of flexibility and it is supposed to be a standard solution in the formal, informal and non-formal education and training.

1.3. The adaptive test model

The model itself consists of two main modules: the Test Module, which consists of the Educational Ontology, Testbank; and Adaptive Testing System. The modules are embedded in any kind of e-Learning environment, which contains a Learning Management System (LMS) and a Learning Content Management System (LCMS).

1.4. The e-learning environment

The user logs into the system throughout a Learning Management System (LMS). This system is connected to a Learning Content Management System, where the given teaching materials are implemented, and accessible for studying. The content of the teaching material has been developed according to the SCORM standards. The LMS is responsible to communicate with the Test Module. During the testing process, the user answers the questions, which are sent by the Adaptive Testing System (ATS) within the LMS.

1.5. Educational Ontology

The Educational Ontology plays a key role in setting into operation the Test Module and also has an indirect influence on the functioning of the whole learning environment. Primarily, the ontology aims at capturing and modelling all knowledge which is part of the curricula of

different education and/or training programs. Besides, a suitably elaborated ontology model will support the adaptive/multistage testing of students by enabling a detailed exploration of missing knowledge and knowledge areas (KA).

'Knowledge Area' is the superclass of the ontology, representing major parts of a given curriculum. Each 'Knowledge Area' may have several 'Sub-Knowledge-Areas', moreover as elements of each knowledge area all of those objects are also listed in the ontology about which questions could be put during testing. These objects are the following: 'Basic concepts', 'Theorems' and 'Examples' of the knowledge area. In order to precisely define the internal structure of knowledge areas relations that represent the connection between the concepts and classes of the ontology are also described. The role of 'premise' and 'conclusion' relations is to determine which basic concepts are used to declare a given theorem and which basic concepts are formed by the declaration of a theorem. The 'refers to' relation determines that the given knowledge element is based on another element of the ontology. Namely, a basic concept or theorem may refer to another basic concept or theorem and an example may refer to any of the other two knowledge elements.

Not only the internal relations, but relations connecting different knowledge areas are also important regarding knowledge testing. A 'Knowledge area' and its sub-areas are connected with the 'part of' relation. Finally the 'requires knowledge of' relation is used to connect a given knowledge area with those knowledge areas that must be learnt in advance.

1.6. Testbank

One pillar of the adaptive/multistage testing system is the Education Ontology that captures and systematizes all the knowledge a student must know. Another pillar of the system is the set of test-questions. When developing a test-question a reference must be given on meta level to a certain knowledge area of the ontology. This means that all the questions in the Testbank must be devoted to one or more knowledge elements in the ontology and any of the knowledge elements may belong to more test-questions. This way the set of test-questions is structured by the Educational Ontology.

1.7. Adaptive Testing System

The system ensuring the development and running of adaptive testing is based on the dual pillar of Educational Ontology and the related Testbank.

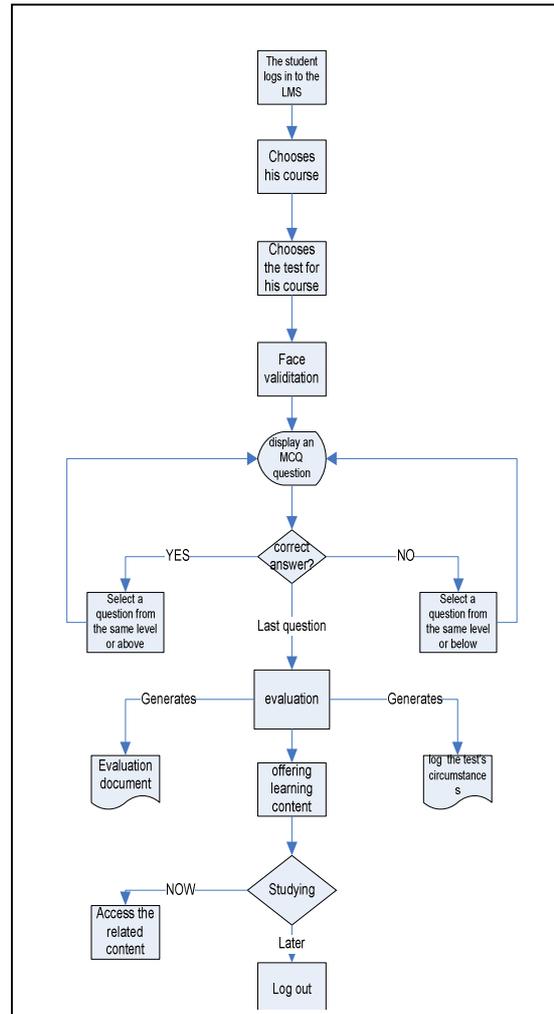
The items of the Testbank are accessible by the reference engine of the Adaptive Testing System which picks the questions based on the structure of the ontology, and the performance of the student. Picking a question from the Testbank (throughout its metadata pointing to a certain knowledge area of the ontology as well) is always determined by the previous answer of the student, the position of the given KA in the ontology, and – in a later development - the difficulty of the questions.

The Adaptive Testing System is also connected to the LCMS. At the end of the test, after the evaluation, the ATS provides links to the teaching content in the LCMS, what should be further investigated by the test taker. This is the ontology based evaluation in brief, which considers the incorrect answers (related to the KAs) of the student.

1.8. Testing

1.8.1. Signing in

The testing process is described by 2. Figure. The test taker, who has to test his knowledge, logs into the system through the LMS. The authentication should be valid for the whole system, which means that with a single sign-on the test taker access all the services, which are provided by the LMS. The tests are assigned to courses, so the student has to choose a course, then a test for that course.



2. Figure: The testing process

1.8.2. Face validation

Before the test starts, a crucial pedagogical step should be included: the face validation. In the related literature, face validation means that the system provides general information for the test taker about the circumstances of the test. This includes information about the length (time, amount of questions) and the type (what kind of questions should be expected) of the test. A sample question is also provided. We decided to use conventional Multiple Choice Questions with one correct answer and three distractors. A test should not only be valid, but reliable as well, which means that it has to indicate the real assessment of knowledge of the examinee. Considering this, a longer test is more reliable. A generally accepted ratio if the test takers administer 60 questions within 75 minutes. The chance of guessing the right answer ('lucky strikes'), which may lead to a false result, is minimal in case of this amount of items.

Test takers also must be told where to get help in case of problems throughout the testing process (e.g. technical assistance).

1.8.3. Filling out the test

The user interface is very simple and clear. After the face validation the user has to start the test procedure. The system provides only one question and the four possible answers for that question at once. After the test taker indicated his/her solution, the system checks whether the answer was correct or wrong and based on this result, puts the next question on the screen. In case the answer is wrong, the system will check the KA in question further (based on the ontology) and chooses a test item from the Testbank.

In case of correct answer the process is repeated in a very similar way. A sufficient amount of questions should be asked from each knowledge areas. If the answer was right the system may choose a question from the same KA with the same or higher level of difficulty or provides a question with the initial strength from another KA. The above described procedure assumes that all the questions in the test repository have predefined strength value, which is related to the importance and the difficulty of the KA.

1.8.4. Evaluating the test

After the completion of the test the system provides a detailed evaluation of the test taker's performance. This evaluation includes the following:

- The number of questions, which have been answered
- The list of wrongly answered questions
- A list of missing knowledge areas
- The grade of the exam (in terms of performance %)
- Links to Learning content, based on missing knowledge areas – customized learning material is provided.

2. Components of E-GREEN JOBS learning environment (Studio)

2.1. Studio System

For ontology management, mapping, and meta-structure creation the Studio² software is used. Studio is a competence based e-learning methodology, and ontology based adaptive testing system.

2.2. Ontology as Knowledge Representation

The most cited definition of ontologies comes from Gruber, who defined these data structure as an “explicit specification of a conceptualization”³. This means ontology explicitly represents a mutually accepted knowledge-base of a specific field. The ontology lists the concepts of a given field as its objects and connects them with relations. In this way the accumulated knowledge of a given field can be formalized and stored. The ontology, which was built this way, can be easily processed and understood by humans and machines⁴. The fact that processing rules can be generated to automatically deal with ontologies makes them a really important structure of semantic applications. To summarize the previous definitions, ontology is a formal structure, which can be read and processed by machines and, based on a common understanding of field specialists, serves as the conceptual frame of a domain and acts as a modelling framework on the given field⁵.

The basis of ontology is a well-defined structure, which consists of sets (also called as classes) and relations between them. The concepts of the domain will be the instances of a given class. Instances can possess attributes and properties which are also in the representational framework of the ontologies. It is the modelling expert’s responsibility to

² Studio – Ontology-based e-Learning System, developed by Corvinno Technology Transfer Ltd.

³ Gruber, Thomas R. (1993). A Translation Approach to Portable Ontology Specifications. *Knowledge Acquisition*, 5(2):199-220. Available at: <http://tomgruber.org/writing/ontolingua-kaj-1993.htm>, viewed 30 October 2014.

⁴ Gruber, Thomas R. (2009). Ontology. *Encyclopedia of Database Systems*, 1963-1965, L. Liu & M. T. Özsu, eds., Springer-Verlag. Available at: <http://tomgruber.org/writing/ontology-definition-2007.htm>, viewed 5 November 2014.

⁵ Studer, R., Benjamins, V.R. & Fensel, D. (1998). Knowledge Engineering: Principles and Methods. *In Data & Knowledge Engineering*, 25, pp.161–197. Available at: [http://dx.doi.org/10.1016/S0169-023X\(97\)00056-6](http://dx.doi.org/10.1016/S0169-023X(97)00056-6), viewed 30 October 2014.

create the basic structure, and to classify the concepts of the domain as individuals of the defined classes. The experts who create the ontologies are also widely called as ontology or knowledge engineers. This process is usually done manually, but there are several research approaches to create feasible methods to automate the ontology creation. If the ontology is created in an automatic or semi-automatic way it is called ontology-learning, which purpose is to support the experts in the ontology creating process⁶.

In the Studio system the aim of the ontology is to represent the universe. As the universe consists of galaxies the ontology consists of sub-ontologies which represent specific domains. One sub-ontology consists of the concept hierarchy of the given domain and the relations which connect those concepts. The structure of the Studio ontology represents an educational concept as the main goal of the system is adaptive testing. Because of the underlying concept, the classes of Studio are labelled e.g. "knowledge-area", "example" or "basic concept"⁷.

⁶ Maedche, A., Staab, S. (2001). Ontology Learning for the Semantic Web. *IEEE Intelligent Systems*, vol. 16, no. 2, pp. 72-79, March/April.

⁷ Vas, R. (2007). Educational ontology and knowledge testing. *The Electronic Journal of Knowledge Management of*, 5(1), 123-130.

“Knowledge Area” is at the very heart of the ontology, representing major parts of a given curriculum. Each “Knowledge Area” may have several Sub-Knowledge-Areas through the “is part of” relation. Not only internal relations, but relations connecting different knowledge areas are also important regarding knowledge testing. This is described by the “is part of” relation. At the same time another relation has to be introduced, namely the “requires knowledge of” relation. This relation will have an essential role in supporting adaptive testing. If in the course of testing it is revealed that the test taker has severe deficiencies on a given knowledge area, then it is possible to put questions on those areas that must have been learnt in advance.

For the sake of testing all of those elements of knowledge areas are also listed in the ontology about which questions could be put during testing. These objects are called knowledge elements and they have the following major types: “Basic concepts”, “Theorems” and “Examples”. In order to precisely define the internal structure of knowledge areas relations that represent the connection between different knowledge elements also must be described.

2.3. *Ontology editor*

By using ontology editor that is based on the educational ontology developers are able to work more efficient. The learning time of this editor is shorter than other general ontology editors. These were some aspects at the development of Studio’s editor:

- Extensible – The training system has to meet the labour markets requirements, so it will require constant maintenance and development.
- Treatment of high volume data – Even one curriculum may consist of several hundred ontology elements, like knowledge areas, basic concepts, theorems etc. So the modelling of all the curricula of a given training program will require even greater capacity.
- Interoperability – This learning management solution includes several different systems and applications. So it must be ensured that all part, even including the ontology, can easily and efficiently communicate with each other.

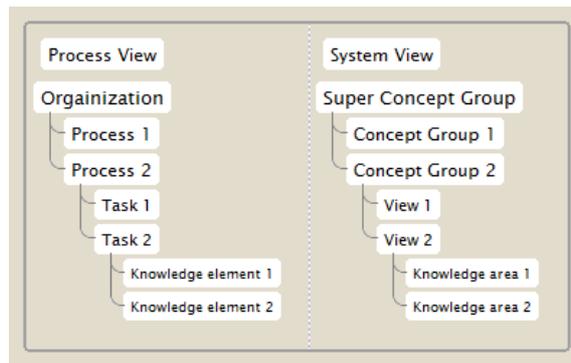
- User friendly interface – a simple but useful interface helps user to work faster and more effectively. The main goal is to create a view of the educational ontology in an understandable way.

2.4. *Ontology Tailoring*

The main goal of any application is to create a task specific meta-structure, by tailoring the domain ontology, based on the knowledge elicited from the organizational business processes. These meta-structures, called as Concept Groups in the Studio terminology, are a new layer on the underlying ontology. A Concept Group consists of knowledge elements tailored from the domain ontology, and rearranged based on the structure of the business process. During the rearrangement the semantics of the domain ontology is retained. In this way the conceptual strength of both the ontology and the process can be retained by mapping them to each other. A Concept Group, created in this way, constitutes as the basis of the adaptive testing.

The result of the text mining process is a set of terms, which are grouped by the tasks of the initial process. A term could be a word or a complex phrase, and represents a knowledge element required to execute the specific task. A term might identify a consistent knowledge element in one of the Studio's subdomain ontologies as well. The identification could be partial or full as a type. The non-identified elements could be transferred to the ontology maintenance module since they could carry added value. Hence the domain ontology can be enriched based on the knowledge elicited from the process.

To summarize the aforesaid, based on the results of the text mining, several consistent ontology nodes can be identified in the Studio ontology. Based on these identified elements of the domain knowledge base, a Concept Group can be created which represents the knowledge from the ontology, required for the execution of the task. If the sets of terms can be combined to a process basis, an adaptive test can be created to facilitate the transfer of the knowledge, required by the given process.



4. Figure: Concept Group representation logic

The concept of mapping the processes into Concept Groups is shown in 4. Figure. As the figure shows, a hierarchy of the Concept Groups could be built in the Studio system, where the class of Super Concept Group represents the organization, a Concept Group represents a specific process in the aforementioned way and Views could be defined to be an entry point to the ontology. A View gives a by task classification of the ontology nodes.

The tailoring of the ontology into a process specific Concept Group is based on the terms fully identified in one of the sub-domains, but a Concept Group is not just a list of terms. The results of the text mining are also enriched based on the ontology, and the structure is stored as well. At the beginning of E-GREEN JOBS initiation, the knowledge engineer can determine a distance value. Based on these distance, possible routes are calculated between the identified nodes of the Studio ontology. This measure is based on graph distance, which is calculated between two extracted concepts found in the ontology. If two concepts are within the distance relative to each other, we assume that the nodes between them are also relevant for the context. This can be done because the ontology can be represented as a graph, where the nodes are the vertices, and the relations are the edges.

The knowledge elements, on these possible routes between the identified nodes, could also be relevant for the process; hence the Concept Groups could be enriched with them. Although with this method the Concept Groups could be expanded with relevant ontology elements, but if the process is automated, than the distance should be chosen very carefully. With an under-estimated distance, relevant elements could be left out and with an overestimated one, irrelevant nodes could be selected and put into the Concept Group. It is a question of future research how the bridgeable distance can be determined. It is also

the subject of future research how other structural strength of the ontology, e.g. relations, can be used during the Concept Group creation.

2.5. Adaptive Testing System

One of the main objectives of the Studio system is to provide adaptive tests, based on the Concept Groups tailored from the ontology. The aim of the test is to discover the potential knowledge gaps of the test taker, and provide a 'map', which could be used as a compass to the knowledge which should be acquired. So every potential user should take a test first. Based on the answers the user gave, the system determines the knowledge gaps and gives a detailed feedback to the user. Based on this feedback the user will be able to acquire and complement the missing knowledge and repeat the process recursively until the whole domain is mastered.

With the help of the Studio adaptive testing system the employees of an organization are able to manage and master their process specific knowledge, which they need to know to fit to their job.

2.5.1. Adaptive Knowledge Testing Approach

In contrast with traditional Testing the number of test items and order of questions in an adaptive test is only determined during writing the test itself with the goal of determining the knowledge level of the test taker as precisely as possible with as low number of questions as possible (Linacre, 2000). Adaptive testing is not a new methodology and despite the fact that it has many advantages compared to traditional testing, its application is not widespread yet. This research has focused on the computerized form of adaptive testing; whose main characteristics – independently from the methodological approach – are the following:

- The test can be taken at the time convenient to the examinee; there is no need for mass or group-administered testing, thus saving on physical space.
- As each test is tailored to a test taker, no two tests need be identical for any two examinees which minimize the possibility of copying.

- Questions are presented on a computer screen one at a time.
- Once an examinee keys in and confirms his answer, he is not able to change it.
- The examinee is not allowed to skip questions nor is he allowed to return to a question which he has confirmed his answer to previously.
- The examinee must answer the current question in order to proceed onto the next one.
- The selection of each question and the decision to stop the test are dynamically controlled by the answers of the examinee (Thissen and Mislevy, 1990).

A methodology of adaptive testing has been elaborated that provides help in determining the knowledge level of the test taker with asking as few questions as possible.

2.5.2. Adaptive Testing Engine

The only task that must be accomplished before starting the construction of the adaptive testing system is to lay down the main principles of our own adaptive testing methodology and work out its process.

The testing algorithm follows the structure of the underlying ontology and uses breadth-first graph traversal. The testing starts from the broadest knowledge area, and goes through the Concept Group till the node representing the most specific knowledge. If an answer, related to a knowledge area, was incorrect, the testing algorithm stops in that branch of the graph, and the questions connected to the children of the incorrectly answered node won't be asked. This means if a question, representing a broader knowledge area of a given domain cannot be answered correctly, the system won't ask questions about the specific knowledge of that domain, i.e. the algorithm automatically assumes that the specific knowledge is not

known. The algorithm behind the adaptive testing module of Studio is also described in detail by an article by Weber et al.⁸.

2.6. Content Authoring

As it was described in the previous section, the ontology provides the underlying structure of the curriculum based learning materials. Every other content developed during the curriculum development process is attached to this structure. This way, all subsystems of the Ontology-based Authoring Environment should be integrated with the ontology layer.

The creation of a new curriculum begins with the selection of the relating domain ontology. Curriculum related learning content, created in the system, should follow the underlying ontology structure that defines the domain of discourse. Since the structure of the curriculum has already been defined, the only task of the content developer is to assign content elements to adequate nodes of the ontology. Content elements can be found in the Repository or they can be created there while attaching them to the ontology.

2.7. Repository

The central element of content development and management is the Repository. This component stores every content element that can be useful in composing a curriculum. Its content can be an image, an article, short texts like a useful paragraph or a famous quote or even audio and video materials. The role of the Content Repository is to store and manage these content elements while maintaining a rich set of metadata describing the contained elements. Each content element can be described with Dublin Core metadata (ISO, 2003) and other useful descriptors, like tags or categories. This rich description enables that stored elements can be easily found and retrieved by curriculum developers.

⁸ Weber, C., & Vas, R. (2014). Extending Computerized Adaptive Testing to Multiple Objectives: Envisioned on a Case from the Health Care. In *Electronic Government and the Information Systems Perspective*. Springer International Publishing. LNCS 8650 (pp. 148-162).

2.8. Test Bank

In order to provide adequate support for knowledge testing several theoretical foundations and conceptions must be laid down concerning the structure of test bank and test items as well. One pillar of the testing system is the set of test questions. Accordingly all test questions must have the following characteristics:

- All questions must be connected to one and to only one knowledge element or knowledge area in the ontology. On the other hand a knowledge element or knowledge area may have more than one relating test question. This way the Test Bank is structured by the Educational Ontology.
- All questions should be weighted according to their difficulty.

2.8.1. Multiple Choice Questions

Test questions will be provided in the form of multiple-choice questions. Therefore parts of a question are the following:

- Question
- Correct answer
- False answers

The Test Bank does not form an integral part of the ontology. This means that questions do not have to form a part of the ontology if we want to represent correctly a given curriculum.

2.8.2. Test Item Editor

As it was seen in the previous section and also in the case of the Content Authoring, Test Authoring is also based on the underlying ontology. The process of Test Development is also similar: questions have to be written and attached to various nodes of the ontology. Naturally, more questions can (and should) be attached to one node. The final phase of the test development process is test generation that means the setting of appropriate testing and evaluation algorithms for a test instance. Multiple tests can be generated using the same question set by setting the parameters differently.

2.9. Packaging

The final step in the curriculum development process is packaging. During this step the curriculum material is packed in concept groups. The concept group contains a part of the ontology, basically the domain or a part of a domain which users should learn. The adaptive testing engine runs the tests based on concept groups also they are used during evaluation. Using this approach content developers are able to create multiple tests for the same domain with different nodes.

2.10. Process of Content Development

As it was described before, development of the curriculum content begins with the construction of the appropriate ontology. Ontology and domain experts determine the structure and concepts of the domain of the curriculum and with the chosen editor tool the ontology is built.

As the ontology is finalized, domain experts extend the bare structure with textual and multimedia content elements. Content elements reside in the Repository. Domain experts can search the repository for already existing content or create new elements if needed. Selected content elements are attached to the appropriate nodes of the ontology. This process is basically the establishment of assignments or relationships between ontology nodes and content elements.

Content developer has to design the curriculum material carefully to maintain a balance between the core and illustration material. Core material is related strongly to the ontology concepts, building the most important and basic elements of the curriculum, while the purpose of illustration elements is to help understanding the material. Core elements are usually textual ones, while illustration material can involve large variety of content elements, like pictures or video clips.

After finishing the content assignment, the Test Bank has to be filled. The domain expert can use the Test Item Editor to edit questions and assign them to the appropriate node of the ontology.

Result of this process is the finished ontology structure with attached content elements and questions. The last phase of content development is the packaging, when the concept groups are made and the result is passed to user for usage.

2.11. Results and learning statistics

Studio offers different approaches to follow the users' activities and results. These statistics are created to help users, give feedback about their progress and to help content developers assess the curriculum. The following options are available currently:

- After each test completed by users the system shows the results, and users gain access to the related contents from the repository.
- Content developers can use some basic statistics implemented in the Studio to follow user activity.
- Content developers can use the Studio's built in query language to write customized query, that can be exported in a comma-separated value file format (CSV file) for further processing. The Studio's query language is based on SQL, so for writing queries the basic knowledge of SQL is useful.
- The Studio's statistics module is reachable for external systems too. In this case external system calls the Studio's module with an HTTP request, which contains a query. The results can be provided in different formats. This way results and user activities can be reached in the external system without manually exporting data from Studio.

2.12. Non-functional Capabilities

- Multilingual environment: The Studio supports translations on the whole system. This means that items of the ontology, repository and test bank can be translated. With Studio content developers have a great tool to create and manage multilingual contents. Studio offers the possibility to translate the interfaces' texts

too. Every time the content or interface text is not available on the required language Studio returns with the default language (English).

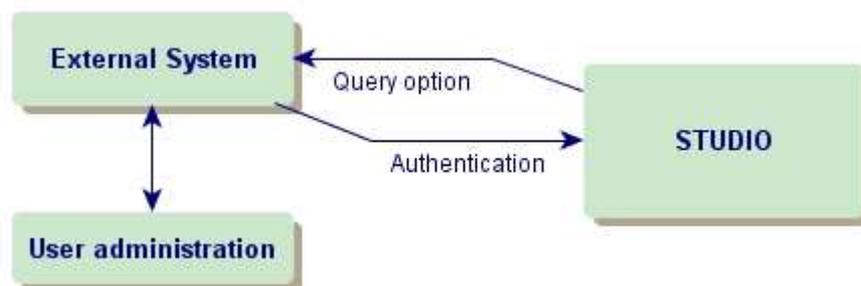
- Scalability: The architecture of the Studio is scalable by using interfaces that runs on the client's browser and databases which were designed with great scalability. The interfaces generate only a reasonable number of requests with small data traffic. For a big number of users it is possible to add additional servers or database server for the architecture.
- Platform independency: One major skill of the Studio to easily adapt to different platforms. The web-based design allows us to create interfaces that will work on different platforms, operating systems and browsers until they support web standards. If the current interfaces do not work for some reason, but it is possible to access Studio server on the platform, developers can build a platform specific interface without disturb the existing ones.
- Loose coupling: From the previous point comes that every interface can be rebuilt without changing the main server. There are only some pattern and communication form that has to be followed for proper working (like the HTTP based communication in JSON or XML format). Work with external systems is the same: Studio works with multiple systems, just the connection patterns has to be implemented.
- Privacy: Studio does not store any additional user information just the user's nick name (or something similar) and the external system's name. This way unauthorized person cannot reach user's identity from Studio, to do that he has to have proper rights in the external system and Studio as well.

3. Architecture of E-GREEN JOBS learning environment (Studio)

There are two points of view of the Studio's architecture needed to be outlined: the connection with other systems and the Studio's inner design. In the first case we are looking at Studio as a black box and only describe the available communication interfaces. After that Studio's inner design will be described with its inner communication model that allows us a better understanding of Studio's background processes

3.1. Connections to External Systems

Studio built as an independent application and runs on its own but requires an external system to authenticate users. After the authentication process Studio will recognize users and allows them to work in the system (5. Figure). This will only allow access to Studio for a limited time and after the session timed out, users need to identify themselves. The session only ends if the user ends interactions with the system. As a web application users need to authenticate at every sign in.



5. Figure: Connections to External Systems

Studio is able to send back information to the external system as well. This includes some basic statistics, user activity, results. This type of feedback is especially important working with LMS to complete the learning infrastructure but will work with other systems too.

3.1.1. Authentication

For authentication and to enter Studio there are two basic actions which have to be implemented; the background communication with the server and creating the entry links for Studio.

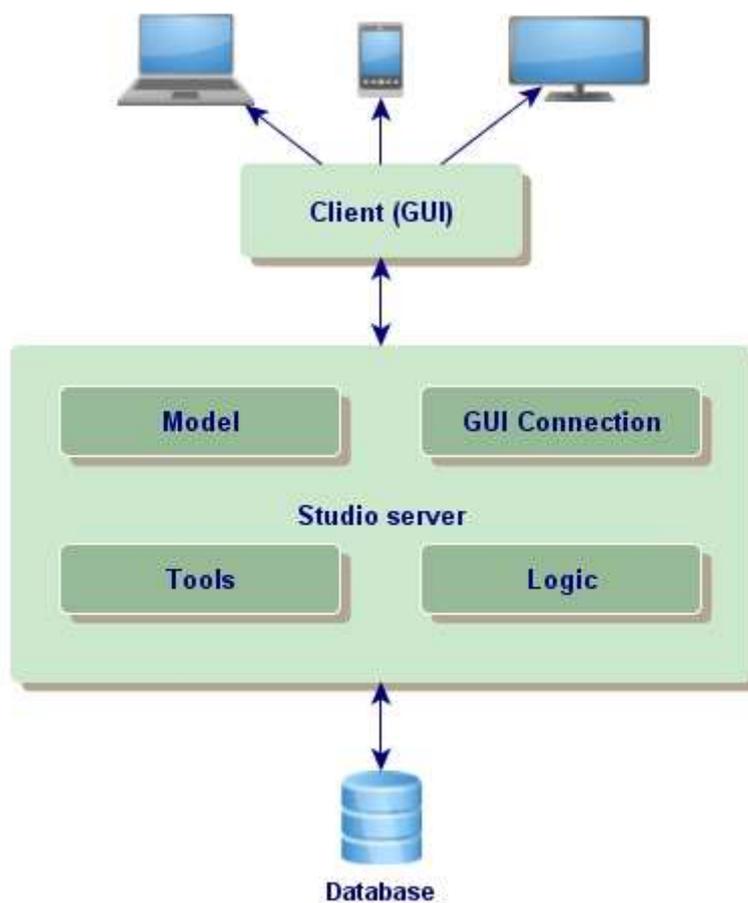
- Studio needs to recognize the external systems server for this the system has built in function which only needs some information about the new system to connect with. The major work of this process is to create the authentication functions in the external system which usually needs development. Studio offers patterns and support for this process. There are test server(s) to try out the communication and test interfaces to work with. The external system gives only some basic information about users like the user's name, nick name, rights and selected language. Rights may be overwritten by Studio.
- The entry links need to be built by external systems, these links could be a simple HTML link (or button that points to the same URL, etc.) or a URL for an *iframe*. In each scenario the links are basically built in the same way, just with *iframes* it is possible to add Studio's interface to an existing web page. Studio offers a pattern to creating links, like selecting interfaces or selecting concept groups for tests. Link has to contain a token which has to be implemented in the external system, and it is used for authentication. The token is the only variable in the link, but it depends on the external system to make the other parameters variable too.

3.1.2. Query option

Studio can send information back to other systems for further evaluation. These can be posted from the external system via HTTP requests. Requests have to contain a query written on Studio's own query language or a basic statistic type and a format parameter. The external system has to implement some major functions to process the data that will send the Studio. Data types can be JSON, XML or some character-separated format like CSV.

3.2. Internal design

Studio has a web-based three-tier architecture which contains graphical user interfaces that can run in user's browsers, a main server and a database layer (6. Figure).



6. Figure: Internal design

3.2.1. Client

The most important issue that Studio's interfaces are not web pages; they are web applications running in web browsers. The major benefits from this design is that users do not need to install software on computers and they only need to download the GUI once, there are no additional page loadings. The interfaces gain their data from the Studio server by sending AJAX requests, and process them.

This approach allows us to implement interfaces on different platforms or browsers. GUI only needs to follow the communication protocols and patterns by Studio.

3.2.2. Studio Server

The main component of the Studio architecture is the Studio Server which handles everything from user authentication to database writing. The GUI can be downloaded from this server after user is authenticated. The server processes HTTP requests and sends the results back to a GUI or other external system like it has been discussed in the previous section.

Server code can be divided into four major types:

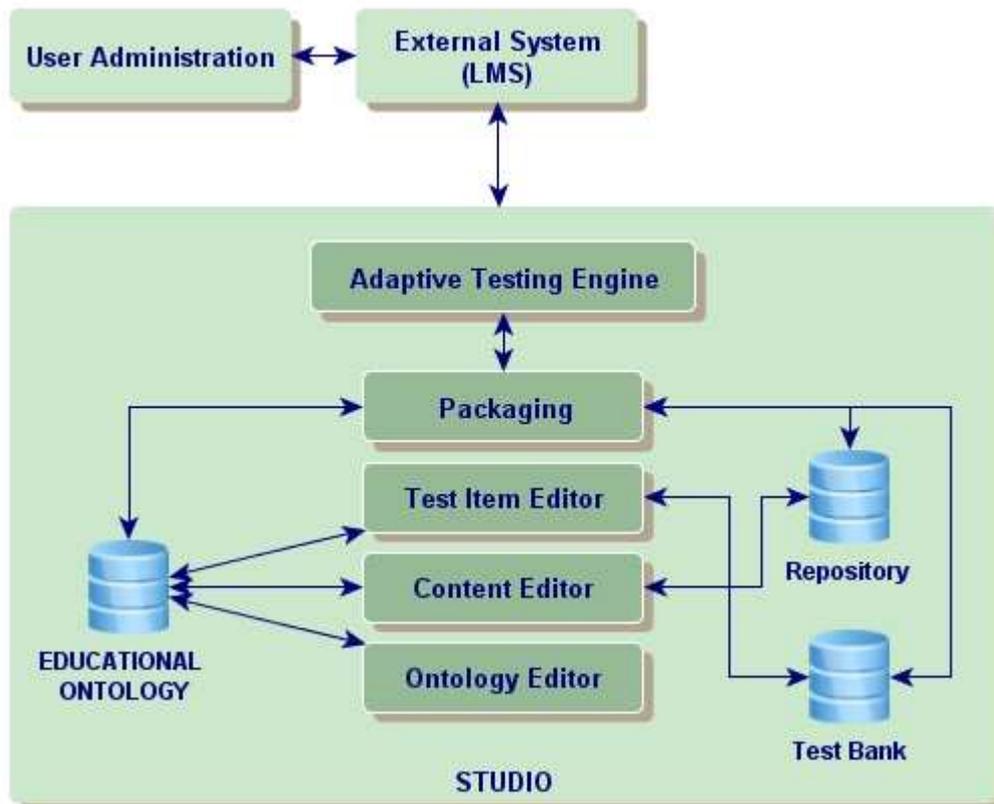
- **Connection:** this part of the code is responsible for the process of HTTP requests; check user rights and parameters; send the results back.
- **Logic:** It contains all core functions of the Studio (ontology editing, adaptive test engine, statistics module, etc.)
- **Model:** model contains all classes that are used in Studio like ontology classes, users etc.
- **Tools:** tools are used by the server's other three main part, mainly these are functions that are used for content encoding, handle databases.

3.2.3. Database

Database runs in the third tier of the architecture, it cannot be reached directly from interfaces, only system administrators can work with them in that way. The database used by Studio is well scalable and easy to use.

The main goal was to create a web-based learning infrastructure which supports the whole learning cycle, independently from its form (e.g. workstation- or mobile phone-based learning). For the proper learning experience Studio is needed to be attached to a Learning Management System (LMS), but because of the authentication processes Studio works with basically any type of web-based system with user administration module.

The Studio main components are the educational ontology, the repository, the adaptive testing engine and the related editors. The connection between components can be seen on **Error! Reference source not found.** This chapter contains the detailed description of the components, their functionalities and the platform's non-functional capabilities.



7. Figure: Structure of Ontology components

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