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# Technology Enhanced Learning for Humanities by Active Learning – The SINUS Project Approach

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***Abstract:*** *The paper presents an approach to active learning facilitated by the use of semantic technologies. Some features of active learning and understanding of learning in humanities are discussed. The specifics of a well defined learning task – learner's authoring of analytical materials, grounded by materials from a digital library – are analyzed to shape the functionality of experimental Technology Enhanced Learning (TEL) environment with a built-in domain and pedagogical knowledge. The environment structure and realization are discussed and a learning example is presented.*

***Keywords****: Technology Enhanced Learning, active learning, learning-by-authoring, semantic technologies, ontologies.*

## 1. Active learning and understanding

The more traditional, passive instructional approaches are based on transmission models of learning, which assume that learners acquire knowledge transmitted to them by some external source (which may be a teacher, a text, or a Technology Enhanced Learning (TEL) system). In fact the instructional system – the instructor or the computer program – assumes most of the responsibility for important decisions in the learning process. The active learning approach is grounded in the constructivist vision of learning, whose academic significance and practical value are generally acknowledged. The constructivist vision argues that learning is an inductive process in which learners explore and experiment with a task to infer the rules, principles, and strategies for effective performance [1]. The active learning approach gives the learner primary responsibility for managing his or her learning (e.g., sequencing the learning activities, monitoring, estimating the learning progress). Researchers have discussed two important distinctions between active and traditional learning: internal versus external regulation of learning, active knowledge construction versus internalization of external knowledge [2].

Therefore the learners have to be stimulated to engage directly with the subject under study, participating actively in the learning situations in order to "construct" their own understanding of the subject – their own knowledge. To understand is to make connections and bind our knowledge together into a mental picture fragment that makes sense of things. But the word understanding denotes not simply a mental act, but also implies doing. The pragmatic target of understanding is to permit effective application of knowledge and skills in realistic tasks and settings.

Researchers, investigating the pragmatic topics of specific active learning form (called also project-based learning), have revealed and clearly formulated a set of significant facets of understanding in the context of learning processes [3]. Their findings point out that when really understands, the learner is able to:

- Explain – to provide justified and systematic accounts of phenomena, facts, and data on the base of basic principles or generalizations; to make insightful connections and provide supportive examples or illustrations.
- Interpret – to offer interpretations and narratives that provide meaning.
- Apply – to use and adapt effectively knowledge in diverse contexts.
- Have a perspective – to see the big picture in which the current knowledge fragment is included; to apprehend critically different points of view.
- Empathize – to be able to get inside another person's worldview and feelings and to find value in what others might find odd, alien, or implausible.
- Have self-knowledge – to be aware of his/her personal style, prejudices, and habits of mind that shape and impede understanding; to have an idea of what is not understood and why it is so hard to understand.

These dimensions of understanding have to be considered seriously in the learning designs in general and especially in the development of more helpful and supportive TEL applications.

## 2. Some characteristics of active learning in specific settings and domains

In the active learning the dominant pedagogical approach is exploratory or discovery learning, organizing the acquisition of new information through activities initiated and controlled by the learner. Exploration can be encouraged by creating an open (not rigidly structured) learning environment and/or by explicitly encouraging trainees to engage in exploratory behaviours.

The modern vision on the active learning extends beyond simply "learning by doing" (useful when acquiring factual and procedural knowledge and/or training skills, based on clear procedures/receipts) and utilizes formal training components to systematically shape and support trainees' learning processes. In fact, the key to active learning is not learners' behavioural activity per se but, rather, their cognitive activity (e.g. selecting, organizing, and integrating knowledge). From this viewpoint in pure exploratory learning (self-performed by the learner) students may fail to reveal the principles to-be-learned and in such case they have nothing to integrate into their knowledge base. The educational research over the past three decades has consistently shown that guided exploration leads to better learning and transfer than pure exploration. The key point is that an appropriate mixture of exploration and guidance can balance the need for learners to be active during learning while also ensuring they make appropriate learning choices [4, 5]. The authors of the present investigation chose to experiment with the "guided exploration" educational approach.

The contemporary research and development efforts in TEL area address the creation of different pre-defined learning situations to facilitate active learners' participation. Active learning in TEL is relatively easy accomplished when learning facts, simple procedures and practical skills. This becomes more complicated in case of more "artificial" academic education, concerning more theoretic, conceptual matters and connected with formation and interpretation of abstract concepts. This is the case when studying e.g. theoretical physics, mathematics, logics, philosophy, etc. [6, 7]. This is valid to a great extent also for education in humanities, irrespective of the significant volume of necessary accompanying factual knowledge. The learners in such disciplines are often not directly engaged with the phenomena and perceptions from the real world (as in learning experimental sciences or technological disciplines), but have to work more with models – domain world representations, as well as with digital presentations of artefacts.

In case of education in humanities, a set of specific features of the humanitarian knowledge has to be considered:

- Availability of big volumes of not explicitly structured (tacit) knowledge;
- Availability of significant for the area, yet differing theoretical models, which cannot be generalized in a common framework;
- Availability of conceptual theoretic frameworks, built on incomplete and inaccurate concepts and notions;
- Existence of different, even contradictory interpretations of phenomena, which cannot and should not be neglected in the learning process;
- More significant impact of linguistic, cultural and even subjective factors on the understanding and explanation of the processes and phenomena.

Due to these specific characteristics the following dimensions of understanding, defined in [3], should attract special attention when formulating general learning goals for different forms of the education in humanities:

- Interpretation – developing learner's abilities to tell meaningful stories; to provide a revealing historical or personal dimension to ideas and events; to make the object of understanding accessible through images, analogies, and models.
- Perspective – developing learner's abilities to regard critically the offered points of view and to evaluate them against "the big picture" in the domain under study.

- Empathy – stimulating learner's abilities and dispositions to find values in another worldview, even when it may seem at first glance odd or implausible.

Obviously all these specifics of the knowledge and learning goals in humanities make more difficult the construction of computer models, on which TEL applications have to be grounded.

There is a common agreement among the researchers in the areas of pedagogy, psychology, cognitive science, etc., that the most important generic skills to be developed in learners are analysis; argumentation and interpretation. These skills are interrelated as the analysis requires interpretation and the argumentation depends on the abilities to analyse and correctly interpret [8]. The importance of the three basic skills is especially emphasized in the education of theoretical and humanitarian disciplines.

Due to the above mentioned specific features, the interpretative component of learning is of special importance for the education in humanities. Generally speaking from an information viewpoint, the interpretation is connected with the abilities:

- to make associative links to independent information sources,
- to formulate assertions on their basis,
- to make inferences from the available knowledge.

Therefore in order to help in the development of the learners' interpretative capacity, the modern TEL systems have to include in their functionality explicit information support to these abilities.

The deliberations above aim to reveal some new desired functionalities of the TEL systems: in addition to ensuring appropriate presentation of the built-in knowledge about the subject under study and facilitating the retrieval of information objects from information repositories they should offer to the learners more direct information help in the development and mastering of irrevocable basic learning skills – analysis and interpretation. The present paper deals with TEL support for specific active learning activities – learner's authoring of analytical materials by intensive use of digital content from multimedia Digital Libraries (DL) for grounding of the analyses. These activities are facilitated by applying semantic technologies to support the learners in the access and filtration of necessary information objects to be analysed during the authoring process, as well as in the evaluation of outcomes.

## 3. Learning situations and learning goals in the SINUS environment

The work presented in this paper was organised under the Bulgarian NSF research project No D-002-189 SINUS, "Semantic Technologies for Web Services and Technology Enhanced Learning" (sinus.iinf.bas.bg). It aims to study possible benefits of applying semantic technologies to TEL and to develop an experimental SINUS software environment implementing some semantic features to help the learners not in general, but in attentively selected and differentiated learning situations. The developing team was motivated and stimulated by the recent findings in active learning, claiming that the pseudo-general solutions have arguable usability and thus focusing on subject and targets specifics. Therefore, the SINUS project attempted to address TEL functionality for well defined and understood learning setting. The rationale and overall targets of the project along with its main results are discussed in more details in [9]. The learning setting considered by the environment and the supported learning goals are discussed in [10].

The aim of the investigations presented here is to assist the advance of the analytical and the interpretative skills of the learners in a given humanitarian field by developing and experimenting a software environment, permitting the so called 'learning-by-authoring', supported by a built-in domain and pedagogical knowledge. The SINUS environment supports well defined specific learning task – development of educational scholarly essays/course theses/projects for pre-assigned by the teacher analyses of the objects under study. The project result is a multimedia document combining a thematically selected by the learner collection of DL multimedia objects, and textual analytical essay, containing analysis of certain object characteristics significant for the pre-assigned theme.

To develop a project of this kind the learner has to perform the following:

1. To construct limited-sized dedicated multimedia collection by guided selection of appropriate semantically annotated DL resources. The collection is aimed to serve as a base for the necessary analysis and as an illustration/ argumentation of theses in the essay.

2. To analyze the selected collection by comparison and debate of objects characteristics, significant for the assigned theme. This step may require modification/enrichment of the already developed collection.

3. To develop the analytical essay as a multimedia document.

The following learning goals are pursued with these "learning-by-authoring" activities:

1. To improve, make more precise, consolidate and extend learner's specific domain knowledge.

2. To advance the analytical skills of the learners and facilitate their application.

3. To train professional usage of digital content by the learners.

The environment guides and consults the learners on the base of its built-in knowledge (implemented by use of semantic technologies):

a) Domain knowledge about the subject under study presenting its concepts and relations, significant from the viewpoint of the learning process. This type of knowledge is substantially objective and hence it is natural to be organized in a set of domain ontologies. The information and learning materials in the used repositories of information objects are semantically annotated in terms of these ontologies.

b) Pedagogical knowledge, reflecting the teacher/expert mental picture about the content, structure and steps to create good analytical essays. More specific part of this knowledge concerns the way to select sufficiently rich and various illustrative materials for good argumentation. This type of knowledge has a mix of objective and subjective characteristics, so concrete learning designs need more active participation of teachers.

The content and usage of both knowledge types have to consider the normal shortage, inaccuracy and even incorrectness of the initial learners' knowledge for the domain and also for the accessible materials and available information support.

The SINUS environment TEL facilities address the following information support to guide/consult the learner in all phases of project development:

- Help the student to formulate concrete query with appropriate ontological terms by using friendly interface.
- Explain some unknown/unclear terms and their relations with familiar concepts, based on the built-in domain ontologies.
- Provide automatic check of the query result correctness (e.g., by comparison against the object features in an exemplary query for given task).
- Facilitate the student's selection of representative objects, as well as their comparison during the phase of analysis by different modes of visualization.
- Perform automatic check of the selected objects adequacy against teacher's criteria – object number, variety, area coverage, etc. The check is made by comparison with the characteristics of formalised internal representation of the learning task, created by the teacher through a Learning Task Editor.
- Generate warnings for errors and omissions in the developed collection.
- Help in evaluating the structure and balance of the resulting analytical document (e.g., availability of the necessary domain concepts in the text and semantic connections among them).

## 4. Development of a collection – model creation and error checking

This chapter is dedicated to the first subtask of the project development process – the construction of dedicated collection of multimedia objects, appropriate for the assigned concrete learning task. There are several reasons to fix the attention on collection development:

- an appropriate collection of objects to be analyzed affects greatly the success of the analysis;
- the collection development helps the learner to reveal the significant object characteristics to be emphasized in the analysis;
- the collection development is grounded essentially on objective domain knowledge, which is easier to be formalised in semantic information schemes;
- in comparison with the other project creation phases, the actions and possible errors during the collection development are more determinable, not too diverse and hence they do not need complex modelling approaches;
- actions during collections development were more easily understood and covered by the main part of the SINUS team (specialists in informatics).

For collection development in SINUS environment the students apply facilities for access to multimedia DL which objects are described by a set of features. With these facilities the student may send queries to search objects with desired features, select some objects from the list of a query result and declare these objects as a (part of) collection. The collection may be homogeneous (containing objects, satisfying the same search criteria), or heterogeneous (containing a group of objects, each one satisfying its own set of search criteria). The formulation of a collection development task contains a list of desired object features. It may also contain quantitative constraints on the collection size, as well as on the elements of each group in case of heterogeneous collection. The constraints are represented by fixed numbers or by modalities of the type of *all, not more than, not less than, at least*.

By means of the environment module Learning Task Editor, the teacher provides a representation of the concrete task for collection development, containing task formulation (as unstructured text) and a possible solution plan (as text and an exemplary set of queries for its implementation).

In order to be functional, a learning system must contain the following basic means:

- Means to check the correctness of the learner's solutions. For such check a model of correct solutions is needed.
- Means to identify the reasons for learner's errors – a model of possible errors is needed.
- Means to propose how to correct erroneous solutions. They analyze the learner's solution by comparison with both models, above mentioned.

The following notions and definitions have been used in the development of these models for collection development problem.

*Operators.* Let $X$ be the set of all objects in DL.

The *query operator* $Q : Q(X_1) = X_2$ presents the execution of the query $Q$ on the set $X_1 \subseteq X$ with a resulting set $X_2 \subseteq X_1$ .

The *selection operator* $S : S(X_1) = X_2$ presents the selection of a subset $X_2 \subseteq X_1$ of the set $X_1$.

The *add operator* $\text{Add:Add}(X_1) = R \cup X_1$ presents the operation to add the elements of the set $X_1$ to the result *R*.

*Elementary step:* the set of a query operator and the selection operator (Fig. 1).

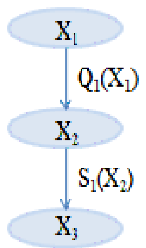


Fig. 1. An elementary step

*Compound step:* a sequence of one or more elementary steps ended by an operator for adding elements to the result (Add).

*Resulting collection:* a set of DL elements, obtained after the execution of all the compound steps.

### 4.1. Creation of a task solution model

In terms of the operators above introduced, a process of finding a possible solution for the collection development task (a solution plan) can be considered as a problem for constructing an operator tree, which root is the entire set of DL objects and the leaves are subsets of such objects representing the desired parts of the collection. In the general case for a given task there exist several correct task solutions (i.e. resulting collections) and hence, several possible ways for finding such solutions (i.e., plans for solving the task). The main purpose of a task solution model is to provide the learning system with a formal description that can be used for:

- Detecting whether a task solution is correct no matter how the solution has been found.
- Detecting all incorrect parts of a checked solution according to a given model of possible errors.

In SINUS environment the solution model of the collection development task is constructed from the concrete task solution plan proposed by the teacher. After entering a textual description of each elementary step from the solution plan, the teacher has to execute the step using the functionality of the Graphical SPARQL Designer for performing such operations as formulating a query, selecting certain objects from the query results and adding the selected objects to the collection. In such a way the teacher constructs a formal representation of a task solution plan as an operator tree. Each path in this tree leading from the root to a leaf corresponds to a plan for solving a concrete sub-task of the initial task. The composition of all query operators (represented as SPARQL queries) belonging to the path determines all *qualitative constrains*, which a subset of the objects from the final collection should satisfy. The *quantitative constraints* are defined through a dialogue with the teacher, who “explains” each selection operator from the path by use of modalities like *exactly N objects, at least N objects, no more than N objects, all objects,* etc.

### 4.2. The model of possible learners’ errors

The SINUS environment allows the learner to perform the assigned learning task in three modes of operation.

1. Independently from the solution plan offered by the teacher, using only the semantic search and explanation facilities of the environment. In this case the environment checks only the final solution of the learner against the qualitative and quantitative criteria set by the teacher for the overall task.
2. Using the system help and the textual recommendations for decomposition of the task to subtasks proposed in the teacher’s plan. The environment does not monitor the elementary execution steps of each sub-task but evaluates the correctness of the sub-task results. The learner has to achieve correct solution for the current subtask before proceeding with the next subtasks.
3. Using step-by-step recommendations of the teacher’s plan and full system help, including monitoring and evaluation of all query results with a feedback to the learner at each elementary step. The learner has to achieve correct solution for the current step before proceeding with next steps.

In all three modes the achieved (intermediate or final) result has to be checked against the following requirements:

a) correctness – if the result contains *only* objects with the desired characteristics;

b) completeness – if the result contains *all* the objects with the desired characteristics.

These requirements form a simple model of the learners' errors for the task "find all the objects, corresponding to the described conditions". The model fits with the classical Information Retrieval characteristics Precision and Recall [11].

### 4.3. Checking a learner's solution for correctness and errors detection

Each set of objects declared by the learner as a final solution of a step, subtask or task is checked by the learning system for correctness and completeness. The concrete algorithm applied for such check depends of the current mode of operation selected by the learner for executing the task. However, in all three cases the check is based on comparison of two sets of objects – the objects found by the learner and the objects that can be found by applying the plan (or the corresponding part of it) proposed by the teacher. The most complicated situation is in the case when the student has decided to solve the task absolutely independently from the plan offered by the teacher[1]. The main steps of the checking algorithm are three.

**Step 1.** Identifying sub-groups of objects in the student solution that can be compared with the solutions of the sub-tasks defined in the task model proposed by the teacher:

- For each sub-task of the task a set of *all objects* satisfying all qualitative constrains defined in the sub-task is created by executing the compositions of teacher's queries describing the corresponding sub-task solution plan.
- Each object from the student's collection is tested for presence against the "teacher's" collection formed at the previous step. In such a way each teacher's sub-task with known requirements is associated with a set of objects from the student's collection.

**Step 2.** If in the student collection there are some objects that are not presented in the collection constructed by the system in the previous step, the student's solution is considered as incorrect and the identified objects are reported as not satisfying the task requirements and proposed to be removed from the final collection

**Step 3.** If every object from the tested collection could be associated as a part of the solution of at least one sub-task formulated by the teacher, the system begins to check the collection at the sub-task level: each sub-task from the task model is checked for:

- What is the number of objects satisfying the sub-task? If no such objects have been identified, the student collection is declared as incorrect and the student is asked for finding additional objects satisfying the concrete sub-task.

[1] An extreme example is a "brute-force" approach to solving the task – querying the system to all objects available in the library and then selecting from them the objects that the student considers as the task solution.

- If at least one object satisfying the sub-task has been found, the check for completeness of the sub-task solution is initiated.
- If the quantitative restriction on the size of the sub-task-solution is satisfied, the student's solution of this sub-task is considered as complete.
- If the quantitative restriction on the size of the sub-task-solution is not satisfied (e.g., the collection contains less objects than it is prescribed by the sub-task description), the system considers the student's solution of the sub-task as incomplete and asks the student to add the necessary number of objects with the specified qualitative features.

A similar algorithm is used for checking the correctness and completeness of the student's solution in the other two modes of operation.

## 5. TEL components of SINUS environment – structure and functions

The SINUS environment consists of three layers – a storage layer containing heterogeneous repositories used for storing data and knowledge; a tool layer containing tools used for data and knowledge processing and a middleware layer used as a mediator between the tools and repositories. In such an environment a TEL application is built hierarchically starting with transforming an autonomous system for storing, accessing and retrieving multimedia data (digital library) into a Web service (basic library), then – into an extended digital library, which is based on Web services and ontologies, and finally – into a TEL system based on Web services (see [9] for detailed description of SINUS environment). In this section we will briefly describe a SINUS tool used for creating TEL application, as well as an experimental TEL application developed in the environment.

### 5.1. Learning Task Editor

The Learning Task Editor is a component of SINUS environments indented for creation of the model for the collection development task. Functionally the Editor consists of several modules realizing such functions as user identification and authorization, task creating and editing, communication with other components of SINUS environment, etc. (Fig. 2).

The main module of the Editor is responsible for creating and editing the task model containing textual description of the task and an exemplary plan for finding the task solution. The plan contains a sequence of steps; each step consists of a text description of what should be done and additional information depending on the step type (elementary or compound) (Fig. 3). The description of an elementary step includes a possible way for solving the step represented as a SPARQL query and the type of quantitative restrictions the objects selected from the list of the query results should satisfy (e.g., exactly five objects or not less than five objects, etc.). A compound step is a sequence of sub-steps (elementary or compound) that ended by an operation assigning objects found at this step as a part of the final solution (i.e., multimedia object collection). The exemplary plan for executing a compound step is assembled from the SPARQL queries solving elementary steps forming the compound step. Each compound step is treated as a sub-task of the initial task. Such decomposition is then used by the Learning System for monitoring and checking for correctness of the solutions proposed by the students when they try to solve this task in different operation modes provided by the system.

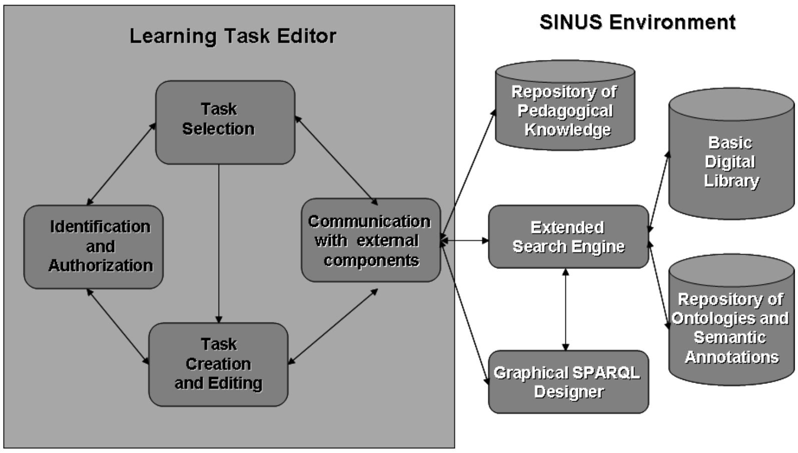


Fig. 2. Functional architecture of the Learning Task Editor

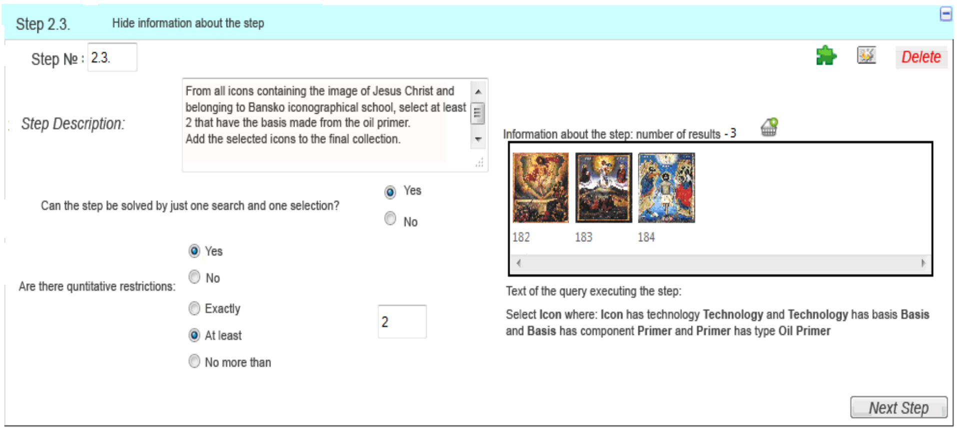


Fig. 3. Creation of an elementary step description

In order to find an exemplary solution of an elementary step, the Editor communicates with the Graphical SPARQL Designer – a special component of SINUS environment intended for graphical creating SPARQL queries and their execution. In practice the user of this component never uses the SPARQL query language – instead, he/she formulates all his/her queries by browsing and selecting the desired objects and properties from SINUS domain ontologies presented in a graphical way (Fig. 4).

Moreover, in order to check the correctness of the constructed query it is shown to the user as a "sentence" written in a "natural language".

To access the complete ontological structure of the objects returned as query results, the Editor invokes a special module (the lifting procedure) of another component of SINUS environment – the Extended Search Engine that converts the non-semantic representation of objects stored in SINUS digital library to RDF-based representation [12]. Such communications with external for the Editor components of SINUS environment are carried out by the communication module. The module is also responsible for loading and storing task models from and to the Repository of pedagogical knowledge.

Fig. 4. A screen for formulating queries in the Graphical SPARQL Designer

### 5.2. TEL demonstrator for collection development

In order to demonstrate TEL abilities of SINUS environment, a learning system assisting students to create multimedia collections satisfying a set of criteria formulated by the teacher has been developed. The system allows the student to solve a collection development task in three different modes of operation – without using any teacher's recommendations, by following the task decomposition plan proposed by the teacher and by following the detailed step-by-step teacher's plan for finding the task solution (see Sub-section 4.2).

The functional architecture of the Learning system is shown on Fig. 5.

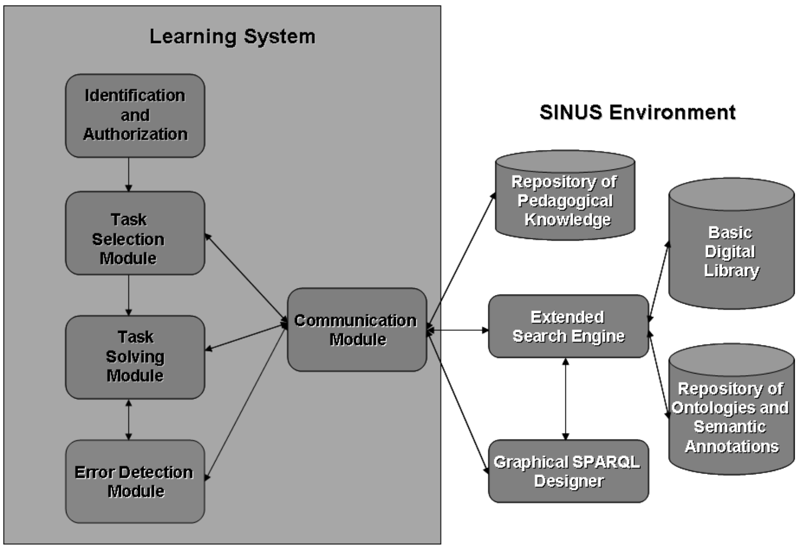

Fig. 5. The Learning System functional architecture

After completing the process for user identification and authorization, the system allows the student to browse all tasks prepared by the teacher, which models are stored in the external for the system Repository of pedagogical knowledge. After selecting a task to be solved the student sets a desired mode of operation with the system and initiates the process for finding the task solution (Fig. 6).

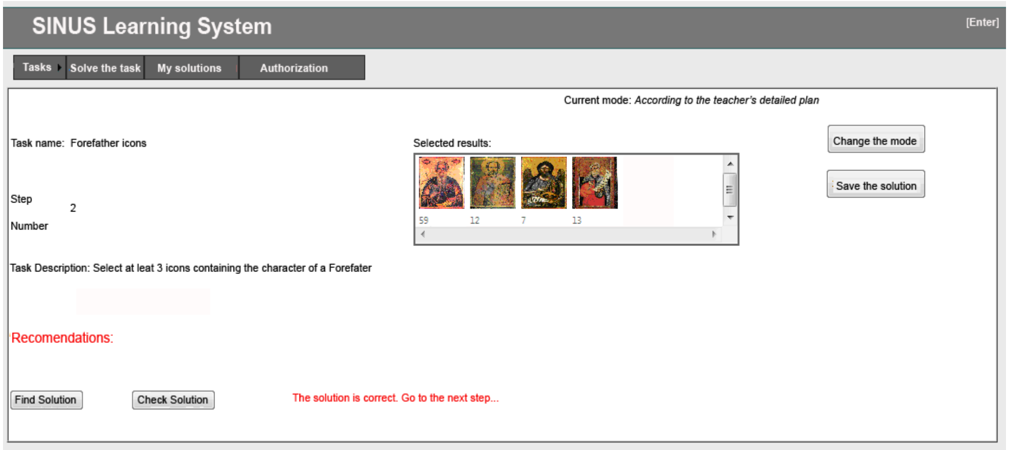


Fig. 6. The screen for solving a task

This process is organized as a sequence of steps consisting of graphical formulating and sending of queries, and browsing and selecting some objects from the query results. All these operations are carried out via the interface of the external for the system component of SINUS environment – the Graphical SPARQL Designer. The number of such operations per step depends on the previously selected mode for solving the task. When the student has got ready with solving the current step, the system checks the student's solution for correctness and completeness and, depending on the results of such a check, either allows the student to continue the process of finding the task solution or reports on the errors detected and proposes what the student should do to solve the current step properly.

The error detection algorithm used in the system is based on matching objects selected by the student as a result of execution of a concrete solution plan step against the composition of SPARQL queries defining all qualitative features that such objects should have. In the current implementation we do not analyze in depth the teacher's queries. That is why the granularity of errors detected by the system depends on the complexity of SPARQL queries used by the teacher for executing elementary steps of the task solution plan. Having in mind this restriction, all elementary steps of the task solution plans used in the project exploitation scenario, have been implemented by SPARQL queries specifying only one desired feature for objects to be searched. As a result, the system has been able to identify not only which objects from the student solution do not correspond to the task requirements but also what requirements the objects do not satisfy.

# 6. An exemplary learning situation

## 6.1. An exemplary learning task

The SINUS TEL environment was experimented in a concrete humanitarian domain – Bulgarian iconography, which has educational uses in a set of disciplines, such as iconography, arts, history, culture studies, theology, etc. Objects from the digital library “Virtual Encyclopaedia of the Bulgarian Iconography” [13] were used as a source material for experimentation. The semantic annotation and search of digital objects is based on the domain ontology for Bulgarian iconographic objects [14]. It is implemented as a set of basic ontology, reflecting only features implicitly built in the structure of the DL, and additional small ontologies of iconographical techniques and iconographical images. This approach to semantic modelling of the domain allows keeping intact the content, annotation and access method of the used DL and at the same time it enables the enrichment of the semantic access to the DL information objects by additional descriptive (ontological) features through attachment of additional specialized ontologies.

Below an example of a concrete analytical project development is presented by a formulation of the learning task (Table 1) and a possible plan for collection development.

Table 1. Formulation of a learning task

| | |
|---|---|
| Task | Make critical art analysis of the chronological development of the iconographic image of Jesus Christ in the iconographic schools from Bansko and Triavna |
| Stage 1 | ***Select a collection of objects for the analysis*** |
| Requirements | The collection has to contain:<br>iconographical objects with the person of Jesus Christ in one-figure images, as well as in multi-figure compositions – iconographical scenes (Jesus Christ feasts);<br>all iconographical objects from 18th and 19th centuries<br>at least six iconographical objects from the same iconographic school |
| Stage 2 | ***Make analysis of the collection*** |
| Recommendations | Examine the selected objects, comparing:<br>• the clothes, gestures, proportions of the person of Jesus Christ;<br>• Christian symbols, other elements around the image of Jesus Chris;<br>• for the multi-figure compositions – foreground, background, other persons.<br>Search for changes – appearance or lack of elements (objects, symbols, persons), changes in background, clothes, etc. |
| Stage 3 | ***Register the results of the critical art analysis as a project*** |
| Recommendations | The project to be formed as multimedia document containing the selected iconographic images together with explanatory text before/after each image |

A possible detailed plan of the collection development for the learning task from Table 1 is shown below:

1. Add to the collection at least six iconographical objects from Bansko iconographical school dated to the period 18th-19th centuries representing the image of Jesus Christ in one-figure, as well as in multi-figure compositions.
    1.1. Find all objects from Bansko iconographic school with the person of Jesus Christ.

1.2. From the list with search results find all objects created in 18th and 19th centuries.

1.3. From the list with search results find at least three objects with the image of Jesus Christ in one-figure composition and at least three objects with the image of Jesus Christ in multi-figure composition.

1.3.1. From the list with results from step 1.2 find all objects with the image of Jesus Christ in one-figure composition.

1.3.2. From the list with search results select at least three objects and add them to the final collection.

1.3.3. From the list with results from step 1.2 find all objects with the image of Jesus Christ in multi-figure composition.

1.3.4. Select at least three objects from the result list and add them to the final collection.

2. Add to the collection at least six iconographical objects from Triavna iconographical school dated to the period 18th-19th centuries and representing the image of Jesus Christ in one-figure, as well as in multi-figure compositions. (Due to the same requirements for the objects from both iconographic schools, Steps 2.1-2.3 to follow are totally analogous to Steps 1.1-1.3 above).

## 6.2. Collection development

Below two examples are shown of incorrect or incomplete development of a collection for the learning task from Table 1. The error checking algorithm has detected the problems on the base of the plan above and corresponding error messages have been issued.

*Situation A (incorrectness)*. The student has developed a collection following the task decomposition plan proposed by the teacher, but not the detailed step-by-step plan. He/she has selected four icons from Bansko Iconographical school dated to the period 18th-19th centuries and representing the image of Jesus Christ in one-figure compositions and three icons with the same image in multi-figure compositions. However, the student has erroneously selected the icon with ID 221 that belongs to Samokov iconographic school. Fig. 7 presents the reaction of SINUS TEL environment.

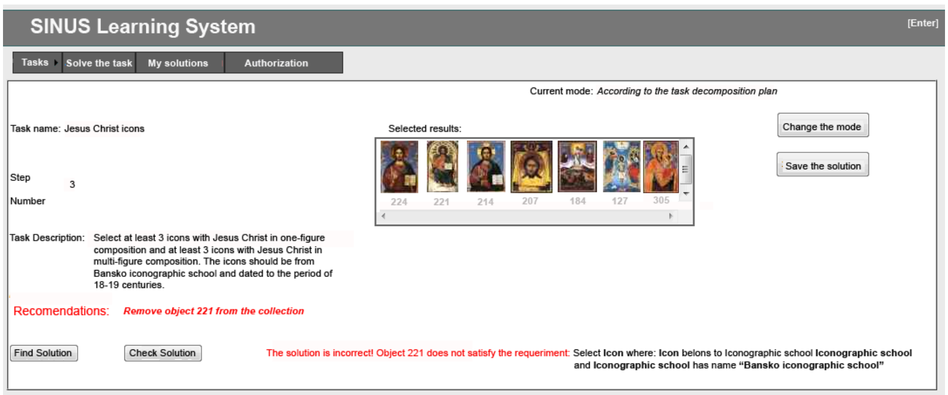


Fig. 7. Detection of an incorrect solution

*Situation B (incompleteness).* The student has developed a collection in the same mode of operation – following the task decomposition plan proposed by the teacher. He/she has selected 6 icons from Bansko Iconographical school dated to the period 18th-19th centuries. In their collection four icons represent the image of Jesus Christ in one-figure compositions, but only two icons – in multi-figure compositions, which is not enough. Fig. 8 presents the reaction of SINUS TEL environment.

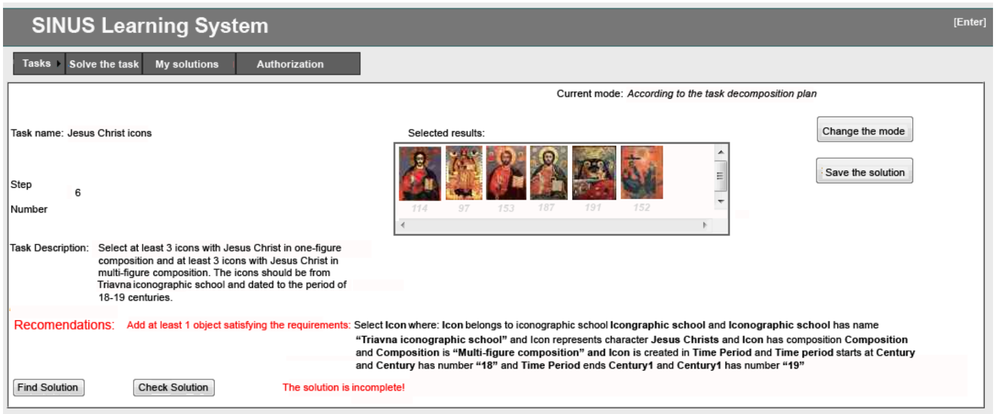

Fig. 8. Detection of an incomplete solution

## 7. Conclusions and future work

The authors selected and determined the characteristics of a well defined and non-trivial learning task. They were motivated by the current educational theories, which focus on the specifics of the learned subject and target audience, as well as on the lessons learnt through decades of research in knowledge technologies, stating that effective problem solving may be achieved only by attracting sufficient volume of problem-specific knowledge. This led to attentive differentiation and clear definition of the specific learning setting – learner's creation of analytical materials by intensive use of the digital content from multimedia DL to ground the analyses. The learning setting considered wide but specific target audience (learners in humanities) and a specific subject under study (Bulgarian iconography).

The necessary types and content of explicit built-in knowledge were identified and formalised in order to support the learners in performing the selected learning task, taking into account the specifics of the knowledge and learning goals in humanities. The proposed approach to semantic modelling of the domain knowledge consists in combining a basic ontology, describing only features, explicitly or implicitly built in the structure of the used DL, and additional specialized ontologies. This approach allows keeping intact the content, annotation and access method of the DL used and at the same time it enables the enrichment of the semantic access to DL information objects by additional descriptive (ontological) features through attachment of specialized ontologies.

The focus of the analysis was put on the learner’s actions during the first phase of the defined learning task – the development of a dedicated collection of DL multimedia objects. Though seeming simpler and easier to be formalised, this phase has a potential for different levels of non-prescriptive active learner’s behaviour in the three possible modes of operation with the designed TEL environment. The proposed models of correct solutions and of possible learner’s errors shape the developed error detecting algorithm, checking the correctness and completeness of the learner’s solution irrespective of the way he/she has obtained it.

These design decisions shaped the functionality of the experimental SINUS TEL environment, implemented using up-to-date semantic technologies.

Many directions for future work on the presented approach are possible, among them:

- Extensions of the model for correct solutions (and, correspondingly, of the error detection algorithm), e.g., with explicitly announcing: obligatory and recommendable requirements; local (to be satisfied on a given step) and global requirements (to be satisfied only after completing the whole collection). Such extensions would help the teacher to define more complex requirements and more complex plans for their achievements.
- Attacking the challenges to provide information support to the learner at the next more complex phases of the investigated learning task – the phase of analysis by guided comparison of the collection objects features and the phase of creating a balanced analytical text with sufficient coverage of desired characteristics. There are some preliminary ideas to apply text processing and data mining techniques, backed by ontological knowledge, to check the availability of the necessary domain concepts (e.g., from the concrete task formulation) in the learner’s analytical text and the possibilities they are semantically related to.

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