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# INTELLIGENT SYSTEM FOR LEARNERS' KNOWLEDGE SELF-ASSESSMENT AND PROCESS ORIENTED KNOWLEDGE CONTROL BASED ON CONCEPT MAPS AND ONTOLOGIES

Alla Anohina [1], Vita Graudina [2], Janis Grundspenkis [3]
Riga Technical University
Kalku Street 1, Riga LV-1658, Latvia
[1] E-mail: alleila@algs.lv
[2] E-mail: vita@cs.rtu.lv
[3] E-mail: jgrun@cs.rtu.lv

## KEYWORDS

Intelligent system, knowledge assessment, process oriented learning, concept map, ontology

## ABSTRACT

Emerging of knowledge-based society and rapid growth of technology put forward necessity to develop human resources through acquiring of qualitative knowledge accordingly to today's requirements of labour market and tendencies of global economy. The quality of knowledge depends on the quality of teaching and learning process which, in turn, has strong connection with assessment of knowledge. The paper describes an intelligent software system based on concept maps. It has been developed with the purpose to improve a technique of knowledge assessment within an educational institution through the support of process oriented learning and knowledge self-assessment. The main questions are related to the system's functionality, testing results and use of ontologies in the further development of the system.

## INTRODUCTION

Nowadays a new type of society - knowledge society - emerges as consequence of replacement of industrial age by information age. Furthermore, constantly increasing influence and rapid growth of technology force employers to put forward demands for highly skilled and educated workforce. Thus, knowledge is becoming the most important asset and it is necessary to develop human resources in order to ensure the competitiveness of a state on world arena in the nearest century.

It is obvious, that the harmonized development of a whole state is possible only under condition of the harmonized development of its all regions. Therefore, it is important to develop human resources in regions, increasing an educational level, promoting improvement of professional skills, and retraining of workforce accordingly to today's requirements of labour market and tendencies of global economy.

The quality of knowledge, which a person acquires within an educational institution, depends on the quality of teaching and learning process, which, in turn, has strong connection with assessment of reached knowledge level. The main value of knowledge assessment lies in feedback, which gives important information both to a teacher and to a learner. This information can be used for knowledge management. The teacher can manage learners' knowledge by tracking and assessing a level of their knowledge at each stage of a learning course. Assessment results may be used to analyze quality and suitability of learning material and to change teaching methods for the purpose of learners' progress towards achievement of the desirable knowledge level. Thus, the teacher should put into practice the concept of process-oriented learning. Knowledge management from the learner side is related with the keeping track of his/her progress in learning by means of knowledge self-assessment. However, knowledge assessment very often is limited only with final assessment, and knowledge self-assessment is ignored at all.

The Department of System Theory and Design of Riga Technical University has developed an intelligent software system based on concept maps for learners' knowledge self-assessment and assessment from the teacher side during a learning course. Regardless the fact that the system was created for assessment of students' knowledge at university, it can be used in any other courses from school learning courses up to retraining courses because it is enough that a teacher is capable to create concept maps. Furthermore, the system is a Web-based application that makes the developed system to be usable at any regional institution, which has the Internet access.

The remainder of this paper is organized as follows. The next section presents such underlying concepts of the system as process oriented learning, knowledge self-assessment and concept maps. After that, the architecture and the scenario of the system's interaction with its users are described. Further, the detailed results of the system testing in four different learning courses are discussed. At the end of the paper some questions related to the use

of ontologies in the future development of the system as well as conclusions are presented.

## UNDERLYING CONCEPTS OF THE SYSTEM

The qualitative teaching and learning process is achievable under condition of assessment not only of the final result, but of process of knowledge acquisition itself. When assessment is made at the end of the learning course it is impossible to determine at what learning stage a learner has met difficulties, which as a result have led to, incomplete or insufficient development of knowledge and skills and it is also already late to start any remedial actions. Regular assessment of learner's knowledge level allows to analyze suitability and quality of learning content and teaching methods and to change them timely to promote the learning course towards achievement of desirable learners' knowledge characteristics. Thus, an emphasis of regular assessment during teaching and learning process promotes process-oriented learning.

In process-oriented learning, a teacher divides a learning course into stages. The notion of the stage is not strictly defined and it can be any logically complete part of the learning course, for example, a chapter or a topic. At the end of each stage the teacher makes assessment of learner's knowledge level.

Trying to achieve qualitative teaching and learning process it is also important to support self-assessment of learners' knowledge. The knowledge self-assessment allows the learner to keep track of his/her progress in learning, thus, promoting more realized approach to the learning process and performance of tasks. Providing opportunities of knowledge self-assessment, the teacher can inform about his/her expectations from the learning process (Anohina et. al. 2006), and tracking results of knowledge self-assessment to adjust learning process, making it more individualized.

In the proposed system assessment is based on the notion of concept maps. Concept maps are a method for representation and measuring of individual's knowledge (Croasdell et. al. 2003) by the means of a visual model, which uses nodes and arcs that represent concepts and conceptual links, respectively. The way how concept maps can be used for knowledge assessment in the context of process oriented learning, as well as an example of a concept map for the learning course "SQL Fundamentals" is given in (Anohina et. al. 2006).

## ARCHITECTURE AND FUNCTIONALITY OF THE SYSTEM

The developed intelligent system consists of an intelligent agent for assessment of learners' current knowledge level and a group of human agents, i.e. learners who are communicating with this agent. The intelligent assessment agent is a core of the system and it includes the communication, knowledge evaluation, interaction registering, and expert agents now.

The following scenario describes interaction between the system and its two users: a teacher and a learner. The teacher using the system creates concept maps for each stage of a learning course and defines their characteristics. During knowledge assessment the learner gets a structure of a concept map of the current learning stage. The structure is formed by the agent-expert based on the teacher-created concept map and the learner's concept map of the previous stage. At the first stage it is an empty structure with very few initial concepts defined by the teacher. In the subsequent stages new concepts are included in addition with those, which the learner already has correctly inserted during the previous stages. In both cases the set of concepts which should be inserted into the structure of the concept map is given to the learner. The formed structure is delivered to the communication agent for its visualization. The communication agent perceives learner's actions on the working surface, i.e. concept inserting into and removing from the structure of the concept map, and clicking on the buttons of solution submission and window closing. After the learner has confirmed his/her solution, the communication agent delivers the learner-completed concept map to the agent of knowledge evaluation. It compares the concept maps of the learner and the teacher on the basis of recognition of five patterns of learner's solutions (Anohina and Grundspenkis 2006) and generates a feedback which is delivered back to the communication agent and then to the learner. The interaction-registering agent receives the learner-completed concept map from the communication agent and results of its comparison with the teacher-created concept map from the agent of knowledge evaluation and stores them in a database. At any time the teacher has an opportunity to examine concept maps completed by the learner and his/her score. Figure 1 displays the described scenario.

The developed system consists of the three major modules. The administrator module allows to manage data about users, learners and groups of learners, teachers and learning courses providing such functions as data input, editing and deleting.

The teacher's module supports the teacher in the development of concept maps and of examining of learners' final score. Its main functions are the following: automatic providing of information on learning courses taught by the teacher and on learners studying a particular learning course; automatic providing of information about maximum score, the publication status and the date of a particular concept map within a chosen learning course; tools for developing, editing and deleting concept maps; and tools for examining of learner-completed concept maps and score, as well as for deleting of the results.

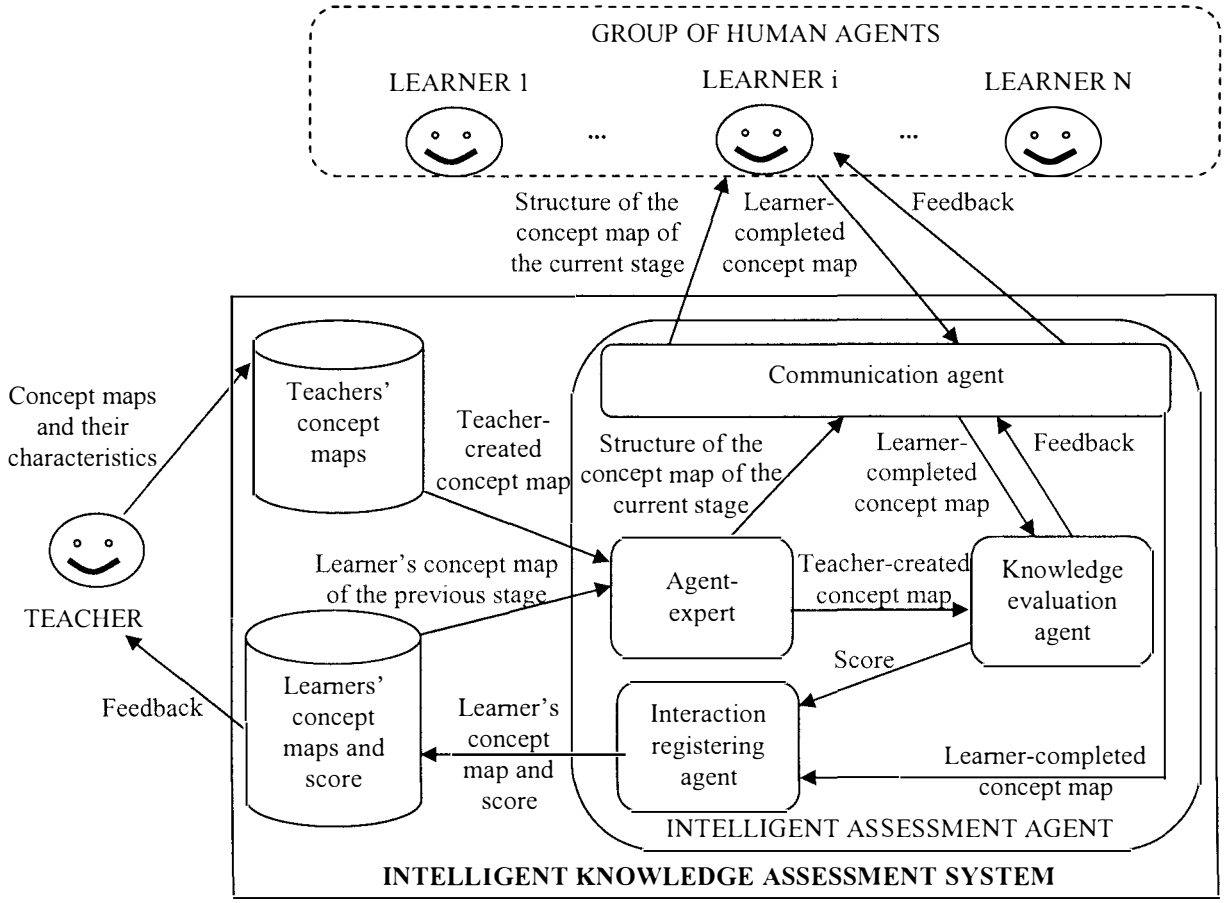


Figure 1. The scenario of the system's operation.

The learner's module includes the following functionality: automatic providing of information on learning courses studied by the learner and on concept maps within learning courses (stage, status of publication and learner's score); tools for filling of concept maps provided by the teacher; tools for viewing feedback after the learner has submitted his/her solution.

The modules interact sharing a common database which stores data about teachers and their learning courses, learners and groups of learners, teacher-created and learner-completed concept maps, learners' final score and system's users (see Figure 2).

The functionality of the system and its client/server architecture in details are described in (Anohina and Grundspenkis 2006). Such system functions as the development of a new concept map by the teacher and examining of learners' results, as well as concept map filling by the learner in the form of use case diagrams are given in (Anohina et. al. 2006).

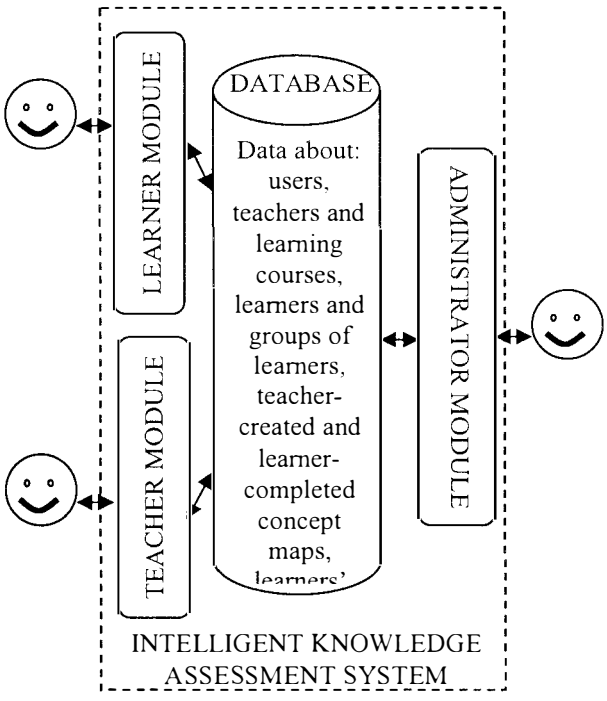


Figure 2. The system's architecture in terms of modules.

## SYSTEM'S TESTING RESULTS

The operation of the developed system has been tested in four learning courses of different types (both engineering and social sciences) in Vidzeme University College and in two institutes of Riga Technical University. Seventy-four students were involved in the testing process. After testing students were asked to complete a questionnaire.

Each questionnaire had fifteen questions, seven of them were devoted to the evaluation of system's performance, and eight questions were related to the used approach based on concept maps. As a result, sixty-three questionnaires have been processed. Let us consider some important questions and students' answers.

**Whether do you understand essence of concept maps?**

Students could choose one of five answers:

A. *Yes and I like this idea*;
B. *Yes, but I do not like this idea*;
C. *No, I do not understand sense of concept maps*;
D. *No, I do not understand how concept maps are developed at all;*
E. *Other answer.*

Figure 3 shows that the majority of students understood essence of concept maps, as well as they positively evaluated the offered idea of knowledge assessment.

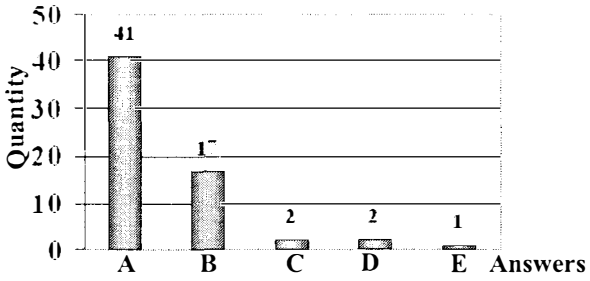


Figure 3. Distribution of students' answers.

**How do you think, whether it is possible to create unambiguous concept maps for a learning course?**

The offered answers were the following:

A. *Yes*;
B. *No*;
C. *Other answer.*

The majority of students (see Figure 4) answered that it is not possible because even if all learners study the same learning course taught by the same teacher, everyone perceives and interprets the information differently. Moreover, the same concept can have a number of interpretations and can be related with different concepts in different contexts.

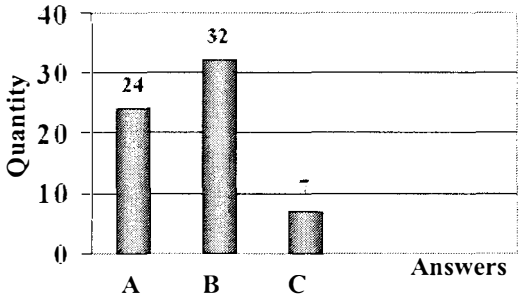


Figure 4. Distribution of students' answers.

**Whether it was difficult for you to fill concept maps?**

Students could choose one of the following answers:

A. *Very difficult*;
B. *Difficult*;
C. *Easy*;
D. *Very easy.*

The majority of students as it is shown on Figure 5 had difficulties when filling concept maps. They explained this fact by the complexity of the offered maps and the limited functionality of the system's prototype.

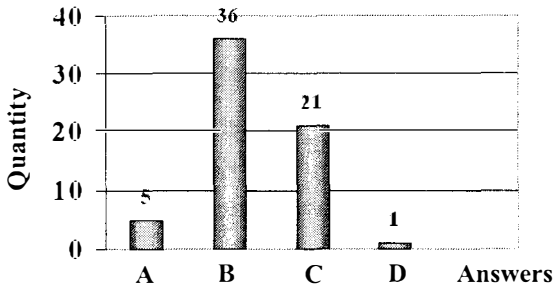


Figure 5. Distribution of students' answers.

**Whether the filling of concept maps has helped you to understand teaching material better?**

The offered answers were the following:

A. *Yes*;
B. *No;*
C. *Other answer.*

Figure 6 displays their distribution. The analysis of answers revealed that concept maps activate thinking and help to arrange the mastered concepts.

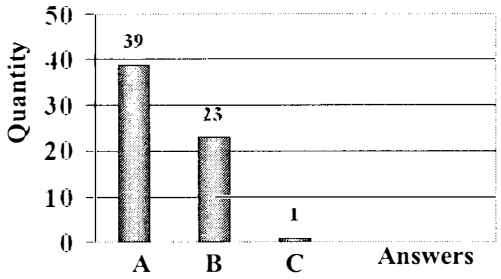


Figure 6. Distribution of students' answers.

**How do you think, whether the filling of concept map helps to objectively assess knowledge?**

Three answers were offered to the students:

*A. Yes*;
*B. No*;
*C. Other answer.*

Students specified that the chosen approach has some level of ambiguity, as well as it cannot assess knowledge perfectly as concepts are only one part of knowledge. Therefore, concept maps cannot objectively assess knowledge (see Figure 7) and they are unacceptable for final knowledge assessment.

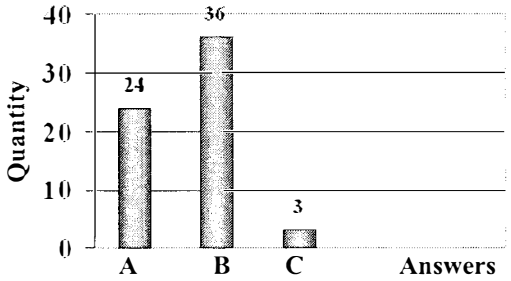


Figure 7. Distribution of students' answers.

**Would you like to use such method of knowledge assessment also in other learning courses?**

Students were offered to choose one of the following answers:

A. *Yes*;
B. *Possibly*;
C. *No*;
D. *Other answer.*

The majority of students agreed to use concept maps in other learning courses (see Figure 8), but only under condition that both the approach to knowledge assessment, and functionality of the system will be improved in future.

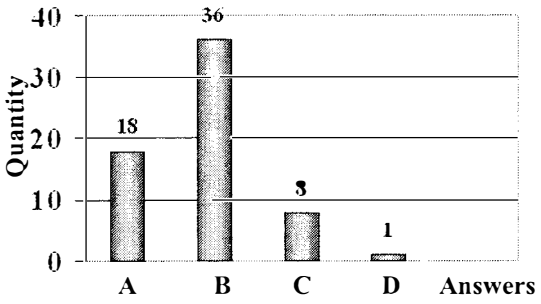


Figure 8. Distribution of students' answers.

Thus, the analysis of the questionnaires revealed that students positively evaluated the chosen approach to knowledge assessment, as well as they specified drawbacks, which gave new ideas for future work.

## ONTOLOGIES AS THE NEXT STEP IN THE IMPROVEMENT OF THE SYSTEM

Analysis of the questionnaires and typical failures of students' concept maps show some quite serious drawbacks, which triggered the current research.

First, system supports only simple links between concepts. Thus, the approach does not provide sufficient learners' knowledge assessment, because there are no possibilities to clarify has the learner mastered correct relationships between linked concepts or he/she has linked concepts without mastery.

Second, the system does not give opportunities to assess learners' skills to organize knowledge structure by him/herself. Now the system offers predefined structure for the concept map and a list of concepts needed to complete the map.

Third, the system does not provide any opportunities to find which concepts are causes for incorrect positions of other concepts and links between them.

Fourth, the system does not give advices and guidance to learners how to improve his/her knowledge level.

In this section, we discuss the foreseen improvements of system's functionality that are focus of ongoing research. We believe that usage of ontologies instead of teacher-created concept maps will help to solve established drawbacks of the system. We are using term ontology according to definition (Gruninger and Fox 1995) that considers ontology as "a formal description of entities and their properties, relationships, constraints and behaviour".

We propose to define course ontology for each study course. It helps to represent study course deeply and widely enough, including constraints on problems domain semantics. First, the ontology provides much

more semantics in contrast to concept maps. The ontology has value constraints, where values of the concept properties are restricted with data types, value range or allowable value list. It also contains axioms and restrictions about concepts linkage. It has enough detailed relations between concepts, e.g. inverse relations and disjoint classes.

We suppose that the usage of ontology in evaluation of learner-created concept maps have some advantages. In cases, when learner's concept maps do not fully match with the predefined ontology, semantic comparison may be performed. This includes searching for the synonyms of concepts and links and checking of concept linking. In cases if concepts are related implicitly, ontology helps to verify if alternative linking is logical. In addition, missing concepts that the learner failed to master in learning activities are identified. It allows providing learners with necessary additional materials that enable to prevent determined weaknesses in concepts mastery.

The system's deployment with ontologies requires also changes in its architecture (see Figure 9). The system may be extended in two directions: the additional database provides the learner with advices and necessary learning materials to improve his/her knowledge level, and the remedial agent finds the appropriate material. Mentioned system's extensions obligate teachers not only to create course ontology but also to prepare materials.

The system's operation is provided by interactions between two intelligent agents: the assessment agent and the remedial agent. Each of these agents consists of several agents. The assessment agent has the same structure as its predecessor in the previous system's version (see Figure 1). The remedial agent is required for analyzing learner's concept maps to determine which concepts are incorrectly mastered. The remedial agent includes the analysis agent and the search agent (see Figure 10), which determine non-mastered concepts and appropriate additional learning material, respectively. The remedial agent also finds which concepts are causes of non-mastery of other concepts. The agent backtracks in predefined course ontology to determine which predecessor concept is incorrectly mastered.

A rather similar approach is proposed in (Jong et. al. 2004) where in concept maps missed concepts are searched using Remedial – Instruction Decisive path. After determination of missed concepts, the agent searches appropriate additional learning materials in the database.

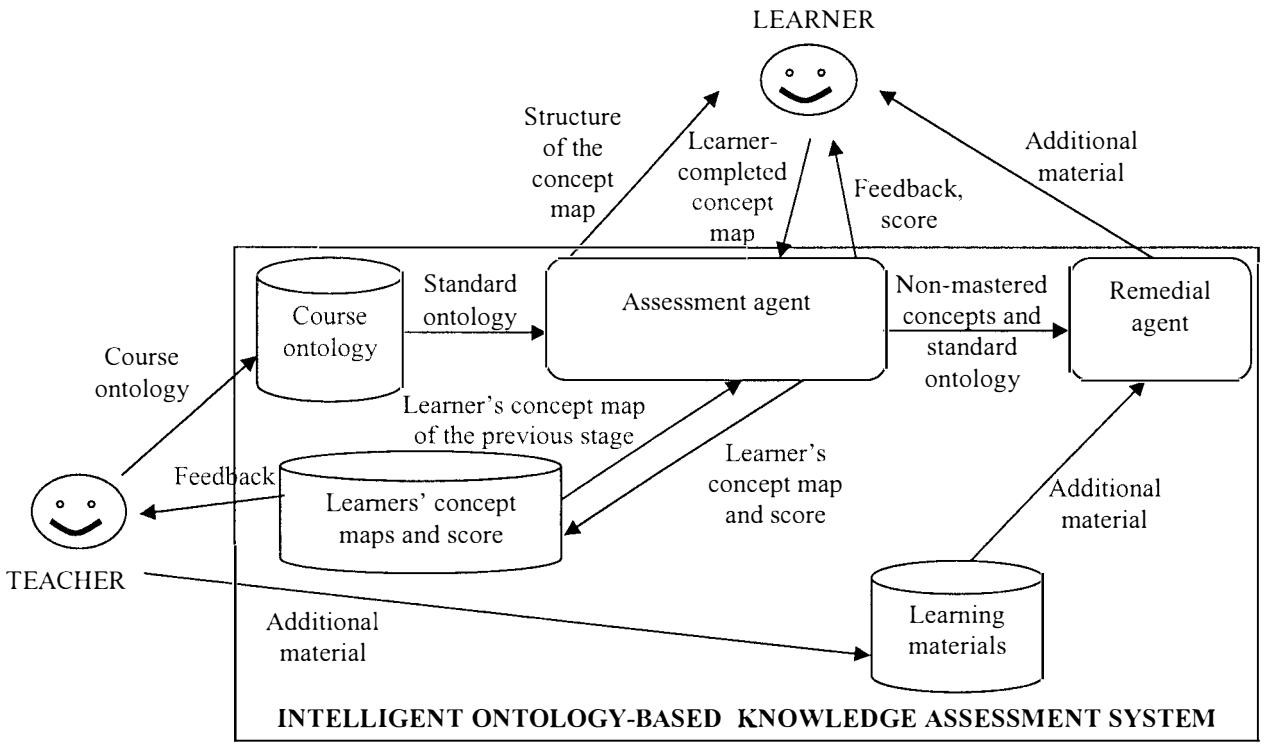


Figure 9. Typical interaction between users and the intelligent ontology-based knowledge assessment system.

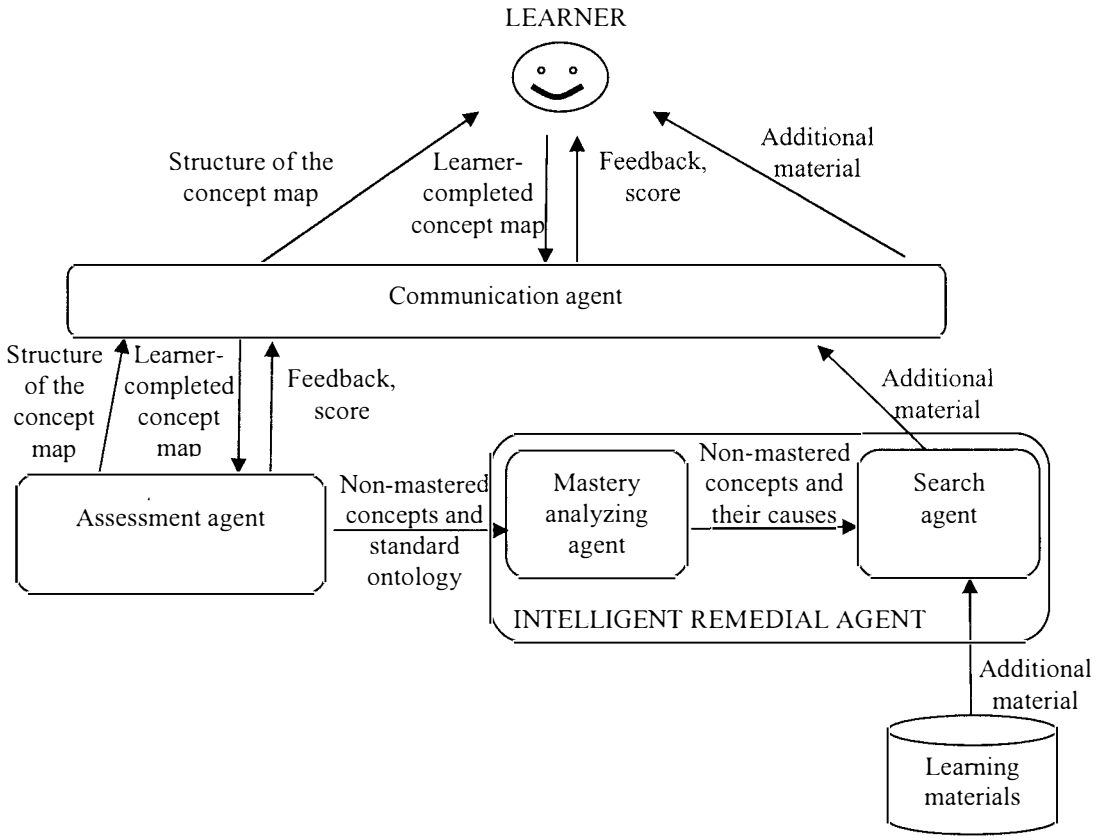


Figure 10. The architecture of the remedial agent.

## CONCLUSIONS

Emerging of a knowledge-based society and growing demand for the highly skilled and educated workforce lead to emphasizing of qualitative aspects of learning. It, in turn, affects not only the content of curriculum and the organization of educational process, but also knowledge assessment.

Acquiring of qualitative knowledge is achievable through the management of this process both from the teacher side through knowledge assessment at each stage of a learning course, and from the learner side by means of knowledge self-assessment. In both cases, assessment results can be used to determine and to remedy knowledge misconceptions and misunderstandings timely. As both assessments demand additional time and cost, they are usually ignored by educational institutions.

Given paper describes a computerized tool- an intelligent knowledge assessment system based on concept maps, which can assist in the mentioned problem solving.

The developed system uses concept maps as a tool of knowledge assessment. Concept maps visually display concepts and relationships between them within problem domain. Thus, the teacher offers such maps as a task for knowledge self-assessment or uses those for knowledge assessment at each stage of a learning course.

The teacher's concept map serves as the standard with which the learner-completed concept map is compared. The system is sensitive to variations of filling the concept maps using for this purpose the intelligent comparison algorithm.

Positive results of system testing in four learning courses that are described in detail in this paper have provided a basis for further development of the system.

One of directions of future work is related with the use of ontologies for deepening knowledge assessment and for generating the recommendation concerning learning material, which a learner should be mastered for filling blanks in his/her knowledge.

Other directions concern refining of feedback, which the system offers to the teacher and the learner, improvements of the user interface of the system and solving of several technical questions.

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## BIOGRAPHY

**Alla Anohina** is an assistant at the Department of System Theory and Design of Riga Technical University. She got M.Sc.ing. in 2002 from Riga Technical University and received Werner von Siemens Excellence Award, Award of Latvian Fund of Education and Award and memorial medal of Latvian Academy of Sciences, Lattelekom Ltd. and Latvian Fund of Education for the best master's thesis in year 2002. Now she is writing her Ph.D. thesis which main topics are intelligent tutoring systems and agent technology. She has five years' experience of teaching in the field of computer science both in Riga Technical University, and in other educational institutions of Latvia.

**Vita Graudina** is an assistant at the Department of System Theory and Design of Riga Technical University. She is graduated with excellence from Riga Technical University in 2005 and received Award of Latvian Fund of Education for the best master's thesis in year 2005. Now she is PhD student at Riga Technical University. The topic of her thesis is the usage of ontologies in different intelligent, information, knowledge-based and tutoring systems.

**Janis Grundspenkis** is a professor at Riga Technical University. He is the director of the Institute of Applied Computed Systems, and the head of the Department of Systems Theory and Design. He got Dr.sc.ing. in 1972, Dr.habil.sc.ing. in 1993 both from Riga Technical University. His research interests are agent technologies, knowledge engineering and management, and structural modelling. He is a member of Institute of Electrical and Electronics Engineers (IEEE) and Association for Computing Machinery (ACM). He is a full member of Latvia Academy of Science.