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CONCEPT MAPS AS THE TOOL FOR EXTENDED SUPPORT OF INTELLIGENT KNOWLEDGE ASSESSMENT

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Abstract. The paper presents the concept map based intelligent knowledge assessment system intended for systematic knowledge assessment. It focuses on the use of concept maps as a tool for extended support of intelligent knowledge assessment through variety of tasks offered, possibilities to extract parameters of the student model, and rich student's support. The paper describes main functional mechanisms of the system and specifies implemented intelligent, adaptive, and adaptable features.

1 Introduction

Requirements of the information age cause new crucially important challenges for universities – necessity to change educational process in order to ensure that graduates will be able to interpret non-standardized information for problem solving and decision making and will have skills of effective turning their knowledge into action. This is possible if knowledge structures of students are fine-developed because qualitatively different cognitive structure and volume of domain knowledge differs the expert from the novice. Universities have potential for reaching this goal by focusing on teaching and assessment methods allowing fine development, elicitation, analysis, and remediation of students' knowledge structures. One of such methods is concept mapping (CM). The number of CM based systems supporting assessment are known, for example, Verified Concept Mapper (Cimolino, Kay, & Miller, 2003), COMPASS (Gouli, Gogoulou, Alexoupoulos, & Grigoriadou, 2008), RFA (Conlon, 2006), HIMATT (Pirnay-Dummer, Ifenthaler, & Spector, 2008). The paper presents the CM based ***i***ntelligent ***k***nowledge ***a***ssessment ***s***ystem called IKAS. It is intended for systematic knowledge assessment which, in contrast to the mentioned systems, is combined with more rich feedback and help possibilities, thus, enhancing use of CMs. The purpose of the paper is to describe how CMs are used to provide extended support of intelligent knowledge assessment. The paper is organized as follows. Section 2 gives an overview of the system and describes student's support. Section 3 discusses intelligent and adaptive features of the IKAS. Conclusions and directions of future work are presented at the end of the paper.

2 Overview of the IKAS

The IKAS has two goals: 1) to promote students' knowledge self-assessment and provide basis for discussion between students and a teacher on concepts acquired in a course, and 2) to support teachers in improvement of courses through systematic assessment and analysis of students' knowledge. The first goal is achieved by a knowledge self-assessment mode, automatic evaluation of students' CMs, and provision of informative and tutoring feedback (feedback further can be discussed with the teacher in order to fill-in gaps in student's knowledge). The second goal is supported by a knowledge control mode, possibility to extend an initially created CM for other assessment stages, and statistics on differences between students' and teacher's CMs. Calculation of student's score is the main difference between two mentioned modes of system operation.

The IKAS supports 3 categories of users: a) an administrator, b) a teacher, and c) a student. The administrator prepares the IKAS for use by other users and manages its default parameters and data related to knowledge assessment process and its participants. Activities directly related to knowledge assessment are split between the teacher, the student, and the system (Figure 1) and they include: 1) creation of a CM by the teacher; 2) reproduction of the teacher's CM by the student during completion of CM based tasks; 3) comparison of the teacher's and student's CMs by the system; 4) generation of feedback by the system.

The scenario of system's use by a teacher assumes that he/she divides a course into several assessment stages. A stage can be any logically completed part of the course, for example, a topic or a module. Therefore, a course includes several modules consisting of certain number of topics. For each module a separate course is added to the IKAS. For each topic of a specific module a CM is created in the IKAS and it forms a CM based task of a particular assessment stage. For each assessment stage a CM is formed by specifying relevant concepts and relations among them in such a way that a CM of a particular stage is nothing else than an extension of the previous one. As a result, the CM of the last topic displays the whole picture of the module.

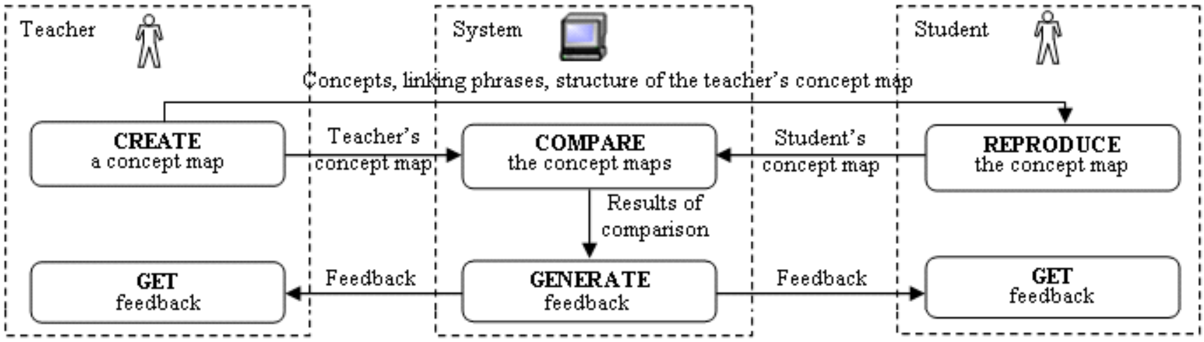

Figure 1. Activities related to knowledge assessment in the IKAS and their actors.

An ideal scenario of system's use by a new teacher and a group of students includes the following activities:

1. The administrator prepares the system for use performing the following steps:
   - register a new teacher in the system by entering his/her first name, last name, user name, and e-mail;
   - register a new course by providing its ID and title, as well as selecting the teacher previously added;
   - add students as users of the system by entering for each of them first name, last name, ID number, user name, and e-mail (role and password are generated automatically by the system);
   - create a new student group by providing its ID and title, as well as adding students previously entered;
   - assign the newly created student group to the previously added course.
2. After completion of administrator's activities, the teacher can start to use the system. His/her steps include:
   - watching system's demonstration files available in the system and explaining its possibilities;
   - adding assessment stages to the course by creating a CM of each stage;
   - setting parameters for the course and the assessment stages;
   - creation of questionnaire(s) for the whole course or particular assessment stages;
   - publishing the assessment stages by selecting their publishing dates.
3. After the teacher has published the assessment stages of the course, the students can complete CM based tasks. They use the system in the following way:
   - watching system's demonstration files available in the system and explaining its possibilities;
   - fill-in the questionnaire on learning styles or change their knowledge level for the course in order to find such degree of task difficulty which is suitable for a particular student;
   - sequentially complete CM based tasks of the assessment stages and use available student's support;
   - view feedback after completion of each assessment stage;
   - fill-in a questionnaire after the assessment stage to which the questionnaire is assigned or after the last assessment stage if the questionnaire is assigned to the whole course.
4. After completion of CM based tasks by the students, the teacher:
   - views and analyzes students' results to find where the course could be improved;
   - views and analyzes students' answers on questionnaires.
5. The students and the teacher have discussion on the completed CM based tasks during the class.

Teacher's CMs serve as reference maps during evaluation of students' CMs. Nodes displaying concepts have: a) a title, b) a definition, description, and example (at least one of the items is mandatory), c) a type: intended for students (a concept that will be available for students during completion of CM based tasks) or initial (a concept that will serve as a starting point for the completion of a task), and d) synonyms. Arcs display relations between concepts. Arcs are characterized by: a) a direction, b) presence of a linking phrase, c) a type defined by the teacher: important relation (weighted by five points and showing that a relation between concepts is considered as important knowledge in the course) and less important relation (weighted by two points and specifying desirable knowledge), and d) synonyms. The following types of linking phrases are used: "is a" – a relation between a class and its sub-class, "kind of" – a relation between concepts from two adjacent levels of hierarchy, "part of" – a relation between a part and a whole, "example" – a relation between a concept and its example, "attribute" – a relation between a concept and its attribute, "value" – a relation between an attribute and its value, and any other linguistic linking phrases.

Six CM based tasks of different degrees of task difficulty (DoTD) are implemented in the IKAS (Table 1) and ten transitions between them are realised. Five transitions increase the DoTD and are carried out automatically if the student has reached the transition threshold (teacher's specified minimum number of points) in the current assessment stage without reducing the DoTD of the original task. Other five transitions reduce the DoTD after a voluntary request from the student (Anohina-Naumeca, Grundspenkis, & Strautmane, 2011).

<table>
<tr><th>DoDT</th><th>Task</th><th>Structure</th><th>Concepts</th><th>Linking phrases</th></tr>
<tr><td>1st – the simplest</td><td rowspan="4">Fill-in-the-map</td><td rowspan="4">Given</td><td>Part of concepts are already inserted into the structure, the other part is given as a list and must be inserted by students</td><td rowspan="2">Inserted into the structure</td></tr>
<tr><td>2nd</td><td rowspan="3">Given as a list and must be inserted by students</td></tr>
<tr><td>3rd</td><td>Not used</td></tr>
<tr><td>4th</td><td>Given as a list and must be inserted by students</td></tr>
<tr><td>5th</td><td rowspan="2">Construct-the-map</td><td rowspan="2">Must be created by students</td><td rowspan="2">Given as a list and must be related by students</td><td>Not used</td></tr>
<tr><td>6th – the most difficult</td><td>Given as a list and must be inserted by students</td></tr>
</table>

Table 1: Tasks Implemented in the IKAS

Operation of the IKAS is based on interpretation of values of parameters available in a student model (Lukashenko & Anohina-Naumeca, 2010). Data in the student model are divided in five sections: a) general data such as first and last name, ID number, e-mail, b) knowledge and mistakes (CMs, scores, concept mastering degrees, individual study plans), c) psychological characteristics (learning style), d) preferences (priorities for types of concept explanation, language of user interface, themes, colours), and e) other characteristics (statistics on use of different types of concept explanation).

The IKAS provides student's support along two dimensions: help and feedback (Table 2). Help assists students in carrying out a CM based task by finding such DoTD which corresponds to their current knowledge level. Feedback presents information about students' progress towards the completion of a CM based task. Help is provided when solving tasks, but feedback can be given both when solving tasks and after their completion (Anohina-Naumeca & Grundspenkis, 2008).

Type	Support	Tasks*	Nature*	Provision*
Help	Changing the degree of task difficulty	F-M, C-M	H	S
	Additional insertion of concepts	F-M	H	S
	Explanation of a concept	F-M, C-M	H, T	S
Feedback	A labelled student's CM	F-M, C-M	I	C
	Quantitative data	F-M, C-M	I	C
	Qualitative data	F-M, C-M	I	C
	Checking of a proposition	F-M, C-M	H, TU, I	S
	A teacher's CM	F-M, C-M	I	C

* F-M-'fill-in-the-map', C-M-'construct-the-map', H-help, T-tutoring, I-informative, S-when solving tasks, C-after the completion of tasks

Table 2: Student's Support Provided in the IKAS

3 Intelligent, Adaptive, and Adaptable Features of the IKAS

The main task of the system is to perform automatic evaluation of students' CMs. This is done in intelligent way by using the teacher's CM as a reference map and a comparison algorithm that is based not only on the isomorphism of both graphs representing CMs, but which is sensitive to the arrangement and coherence of concepts in students' CMs and is capable to recognize partly correct patterns of a student's solution (Anohina, Vilkelis, & Lukashenko, 2009). The algorithm can reveal also so called "hidden" relations in students' CMs which are derivations of relations presented in a teacher's CM. Therefore, students' CMs are compared to the expanded structure where all possible "hidden" relations are added. A set of IF-THEN rules allowing the IKAS to deal with "hidden" relations is developed, for example, IF Relation (X, Y, "Is a") AND Relation (Y, Z, "Is a") THEN Relation (X, Z, "Is a"), where X, Y, and Z are concepts. The rules are used to process longer chains by iteratively going through a CM, searching for patterns, and adding "hidden" relations whenever it is possible (Grundspenkis & Strautmane, 2009).

The student model supports four adaptation operations in the IKAS: selection of the initial DoTD at the first assessment stage and its changing at next assessment stages, as well as setting and changing priorities of types of concept explanation. The algorithm allowing selection of the initial DoTD includes three steps: 1) checking if the student has set the initial knowledge level for a course, 2) checking if the questionnaire on learning styles is filled out by the student, and 3) assigning the DoTD set by the teacher for the course. Transition to the next step is performed only if the previous one gives negative result. "Knowledge Level (KL)-Degree of Difficulty (DD)" rules are applied if the initial knowledge level is set. They assume that if the higher is the knowledge level then the more difficult task must be offered to the student: 1) IF KL = Low THEN DD = 2; 2) IF KL = Medium THEN DD = 4; 3) IF KL = High THEN DD = 6. "Learning Style (LS)-Degree of Difficulty (DD)" rules based on Sequential/Global dimension of the learning style model are used if the student has given answers on the questionnaire on learning styles: 1) IF LS = Sequential THEN DD = 3; 2) IF LS = Global THEN DD = 5.

The algorithm for selection of initial priorities of types of concept explanation also has three steps and the same logic of them: 1) checking if initial priorities of types of explanation are set by the student, 2) checking if the questionnaire on learning styles is filled out, and 3) use of default priorities: "Highest"-Definition, "Average"-Description, "Lowest"-Example. "Learning Style (LS)-Explanation Type (ET)" rules allow selection of initial priorities: 1) IF (LS = Visual) THEN (ET:Example = Highest); 2) IF (LS = Verbal and Sensory) THEN (ET:Description = Highest); 3) IF (LS = Verbal and Intuitive) THEN (ET:Definition = Highest).

Adaptable features of the system available to students include the following ones: 1) adjusting the DoTD by directly changing the knowledge level of the course in the student model or reducing the DoTD during the completion of CM based tasks; 2) adjusting settings of the user interface such as language, theme, etc.; 3) changing approach for receiving of explanations and priorities for different types of concept explanation.

4 Conclusions and Future Work

The development of the IKAS started in 2005 and from version to version its functionality is growing based on usage of more and more possibilities offered by CMs. The IKAS is able to adapt to the current knowledge level of each individual student and to his/her learning style by offering a variety of tasks with different DoTD. Future work is directed towards the development of more mature scoring system which can evaluate student's knowledge accurately and consistently taking into account more aspects of student's activities during solving of CM based tasks and thus avoid certain subjectivity in assessment process.

5 References

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