Learner's Support in the Concept Map Based Knowledge Assessment System

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Abstract: The paper is dedicated to the concept map based knowledge assessment system which has twofold goals in the context of the integration of technology into the traditional educational process: 1) to promote learners' knowledge self-assessment, and 2) to support the teacher in the improvement of the learning course through systematic assessment of learners' knowledge and analysis of its results. The goals are reached by the use of concept maps as an assessment tool and by providing opportunities to extend an initially created concept map for next assessment stages and to present a learner information about his/her errors at the end of each assessment stage. The system has been being developed already for 3 years by continuously improving its functionality. At the moment it offers not only a graphical user interface for manipulations of concept maps by the teacher and learners and the presentation of information about learners' errors, but five tasks of different degrees of difficulty and an intelligent algorithm for the comparison of teacher's and learner's concept maps. Its current development focuses on the identification and implementation of different kinds of learner's support intended not only to help the learner to solve concept map based tasks, but also to tutor the learner during the assessment process. The overview of the system is given specifying its goals and the scenario of usage. Related works are described focusing on learner's support in similar assessment systems based on concept maps. Two dimensions of learner's support are identified, that is, help and feedback, and their different kinds are described in-depth focusing on suitable types of tasks, implementation mechanisms and nature. The paper clearly states which kinds of learner's support have been already implemented in the concept map based knowledge assessment system and which ones are in the stage of the implementation.

Keywords: concept map, knowledge assessment system, learner's support, help, feedback.

1. Introduction

Nowadays when a new type of society, so called knowledge society, emerges knowledge is becoming the most important asset of workers promoting their competitiveness on a labor market and production of a high-value output. Rapidly growing technology and its complexity put forward new demands for highly educated technical workforce, and, as consequence, put in the forefront new challenges for education. Penetration of computer and communication technology into education has changed the educational process and roles of its main actors. Now teachers should be guides and coaches while learners start to turn more and more active ones. Information and communication technologies can support a greater part of activities of the teaching and learning process, inter alia knowledge assessment which plays one of the most important roles in the traditional educational process. A plethora of e-assessment systems and environments have been already proposed and developed which use such methods as objective tests (Castle 2005, Tal 2005, Respondus 2008) that assesses learners' knowledge only at the first four levels of the well known Bloom's taxonomy (Bloom 1956), essay-based assessment (Pérez 2004, Leacock 2003, Sukkarieh 2003) which depends on the learning course and natural language, and offering of tasks specific for a particular domain as it is usually done in intelligent tutoring systems (Crowley 2006, Gascueña 2005). However, functionality of e-assessment system is determined not only by the chosen method, but also by the purpose of assessment. If the goal of the system is to support learners' knowledge self-assessment than it is important not only to provide necessary content (questions, problems, tasks, etc.) and means for the evaluation of learners' answers or solutions, but also appropriate learner's support. The purpose of learner's support is to help the learner to find a task which is the most suitable for his/her level of knowledge and skills, as well as to activate learner's cognitive activity, making him/her to think about acquired knowledge and skills and to ask himself/herself where and why he/she has made errors in the task. Moreover, usefulness and significance of learner's support increases if it takes into account individual characteristics of a learner, that is, it has adaptive nature.

The paper presents a research concerning provision of learner's support in the concept map based knowledge assessment system which is intended to promote learners' knowledge self-assessment and improvement of the learning course by the teacher through systematic assessment of learners' learning results. The paper is organized as follows. Section 2 gives a short overview of the developed concept map based knowledge assessment system. Related works are presented in Section 3.

Section 4 discuses learner's support in the concept map based knowledge assessment system in terms of provided help and feedback. The paper ends with conclusions and an outline of directions for future work.

2. Overview of the system

The development of the concept map based knowledge assessment system started around three years ago (Anohina 2006, Anohina 2007a, Anohina 2007b). It is a Web-based application which uses concept maps as a tool for knowledge assessment. Concept maps are a kind of mental models based on a graph with labeled nodes corresponding to concepts in a problem domain and with arcs indicating relationships between pairs of concepts. Arcs can be directed or undirected and with or without linking phrases on them. Linking phrases specifies the kind of a relationship between concepts. A semantic unit of a concept map is a proposition. Propositions are concept-link-concept triples which are meaningful statements about some object or event in the problem domain (Cañas 2003).

The system has twofold goals in the context of the integration of technology into the traditional educational process: 1) to promote learners' knowledge self-assessment, and 2) to support the teacher in the systematic assessment of learners' knowledge and the improvement of the learning course. It is used in the following way. The teacher defines stages of knowledge assessment and creates concept maps for all of them. The process of the creation of a concept map consists from the specification of relevant concepts and relationships among them as it is shown in Figure 1. Moreover, the concept map for each stage is nothing else then an extension of the previous one because new concepts and relationships are added at each stage. In this case the concept map of the last stage includes all concepts, for example, all concepts taught within a particular learning course, and all relationships among them. Teacher's created concept maps serve as a standard against which the learners' concept maps are compared. During knowledge assessment the learner solves a concept-map based task corresponding to the assessment stage. In the context of the system a task is fill-in or construction of a concept map using an offered set of concepts and/or linking phrases depending on the degree of task difficulty. After the learner has submitted his/her solution, the system compares the concept maps of the learner and the teacher, calculates the score of the learner's result, gathers statistical information and generates feedback which is delivered back to the learner.

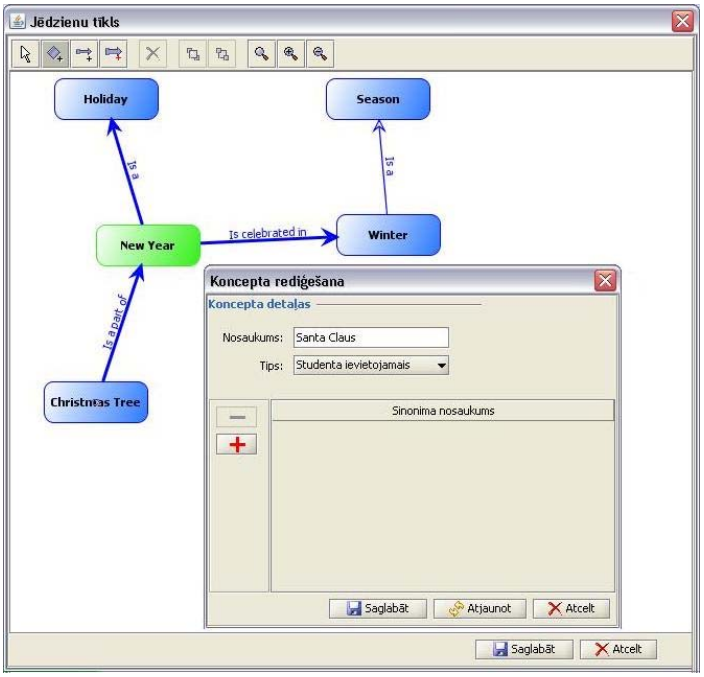

Figure 1: The screenshot of the teacher's user interface (the creation of the concept map)

An algorithm has been developed for the comparison of learner's and teacher's concept maps. It is not based only on the isomorphism of both graphs, but is sensitive to the arrangement and coherence of concepts taking into account such aspects as existence of a relationship, locations of both

concepts, type and direction of a relationship, correctness of a linking phrase, etc. The algorithm is described in detail in (Anohina 2007a).

The system supports learners' knowledge self-assessment as it makes an analysis and evaluation of learners' concept maps, as well as provides feedback which shows the learner's errors. It promotes systematic knowledge assessment because it provides opportunities to extend the initially created concept map for other assessment stages. Moreover, statistical information about differences between learners' concept maps and teacher's concept map is collected providing opportunities for the teacher to improve the learning course.

3. Related works

Nowadays there are a lot of tools supporting different activities with concept maps. However the great part of them provide only such functions as concept map construction, navigation and sharing, but do not analyze learners' created concept maps and do not provide appropriate learner's support in terms of feedback and help. Among tools supporting the latter functions three systems are known.

The simplest kind of feedback is implemented in Verified concept mapper (Cimolino 2003). This tool allows the learner to create concept maps using teacher's defined and learner's added concepts and linking phrases. When a concept map is finished the learner can ask the system to perform its analysis. Results of the analysis include a section "Sentences to ask" which contains messages related to erroneous or missing things in the learner's concept map. Messages are mainly presented in the form of questions, for example, "what is <concept> an example of?" or "what is the definition of <concept>?". However, the actual text presented to the learner is controlled totally by the teacher.

Different kind of feedback is implemented in the system presented in (Chang 2001). The hint button is provided to learners in order to receive an appropriate hint according to the comparison of learner's and expert's concept maps. A hint is given as a partial proposition consisting of a concept and a relation, but hiding other concept. In this case the learner has opportunities to reflect upon learning material.

COMPASS (Gouli 2004) offers informative and tutoring feedback which is adapted to a particular learner on the basis of information (knowledge level, errors made, frequency of errors, number of feedback asked, etc.) stored in the student model. The feedback includes error-task related questions, tutoring feedback and combination of both. The purpose of error-task related questions is to redirect the learner's thinking and to give a hint for correction of the error. Their forms depend on the error category. Tutoring feedback allows the learner to review educational material relevant to the correct answer. Moreover, the authors have identified several categories of learner's errors.

Thus, the first two mentioned tools in comparison with COMPASS do not take into account individual characteristics of a particular learner. Moreover, the analysis of the tools shows that the learner's support and feedback particularly depends on the purpose of the system and offered concept-map based activities.

4. Learner's support

The main goal of the research is to provide richer learner's support in the concept map based knowledge assessment system in comparison with other similar systems. Thus, learner's support is considered along 2 dimensions: provided help and given feedback (Figure 2). The purpose of the help is to assist the learner in carrying out the task by finding such degree of its difficulty which corresponds to his/her level of knowledge and skills. The feedback, in its turn, gives the learner information about the correctness of his/her actions and progress towards the goal, that is, towards the completion of the task. Taking into account the stated purposes the provision of the help is useful during the solving of the task, but the feedback can be given both during the solving of the task and after its completion.

4.1 Help

Three kinds of help are identified for the implementation, namely, changing the degree of task difficulty, additional insertion of concepts and explanation of a concept. Let's consider all of them in detail.

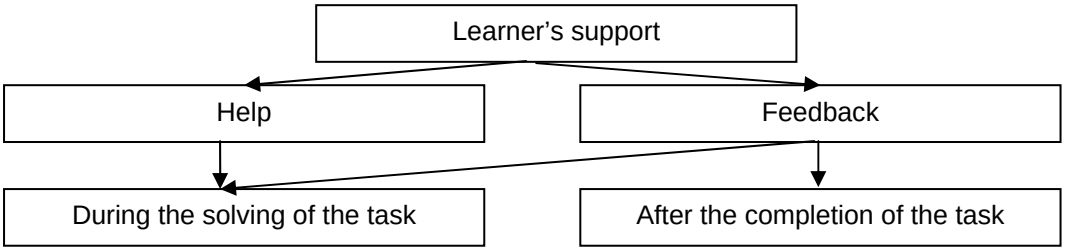

Figure 2: Dimensions of learner's support

4.1.1 Changing the degree of task difficulty

The system offers five concept-map based tasks, which cover both "fill-in" and "construct-a-map" tasks and are ranged from the easiest to the most difficult (Table 1) taking into account information given to the learner and workload needed to complete the task. Figure 3 is a screenshot showing the third level of task difficulty when the learner must fill-in the concept map structure using the given concepts and pointing out relationships between them. Figure 4 shows the user interface at the fourth level of task difficulty when the learner must construct a concept map from the given set of concepts.

Table 1: Tasks offered in the concept map based knowledge assessment system

The type of the task	Ordinal number of the task	The structure of a concept map	Linking phrases	Concepts	Degree of task difficulty
Fill-in	1	Is given	Inserted into the structure	Must be inserted by the learner	The easiest ↓
	2	Is given	Not used	Must be inserted by the learner	
	3	Is given	Must be inserted by the learner	Must be inserted by the learner	
Construct-a- map	4	Not given	Not used	Must be related by the learner	
	5	Not given	Must be inserted by the learner	Must be related by the learner	The most difficult

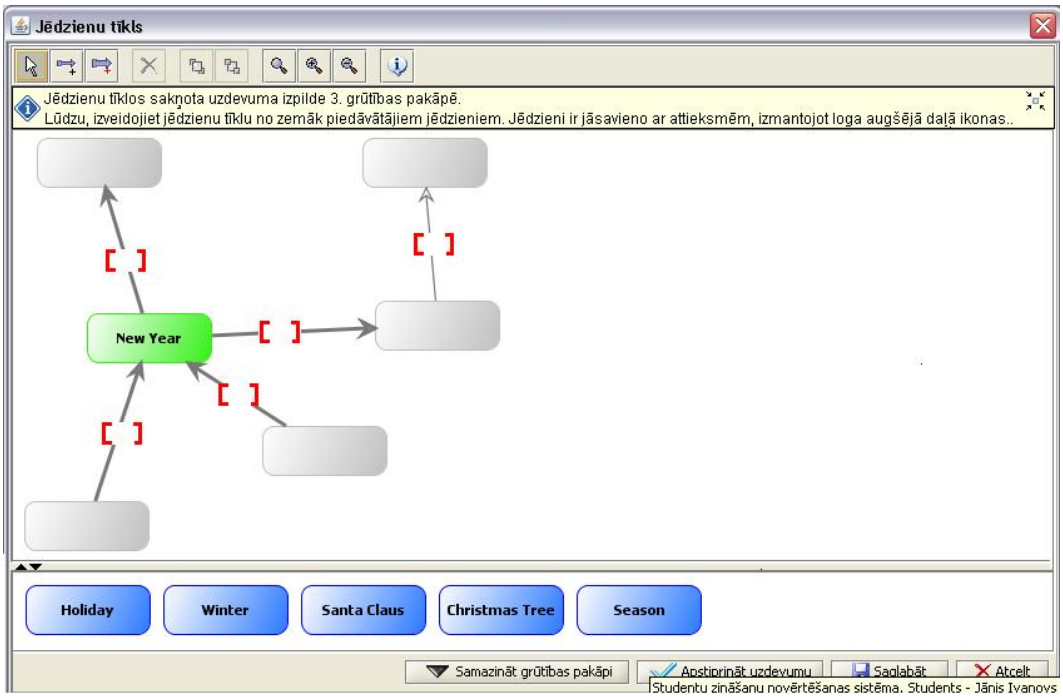

Figure 3: The screenshot of the learner's user interface for the "fill-in" task (the third degree of task difficulty)

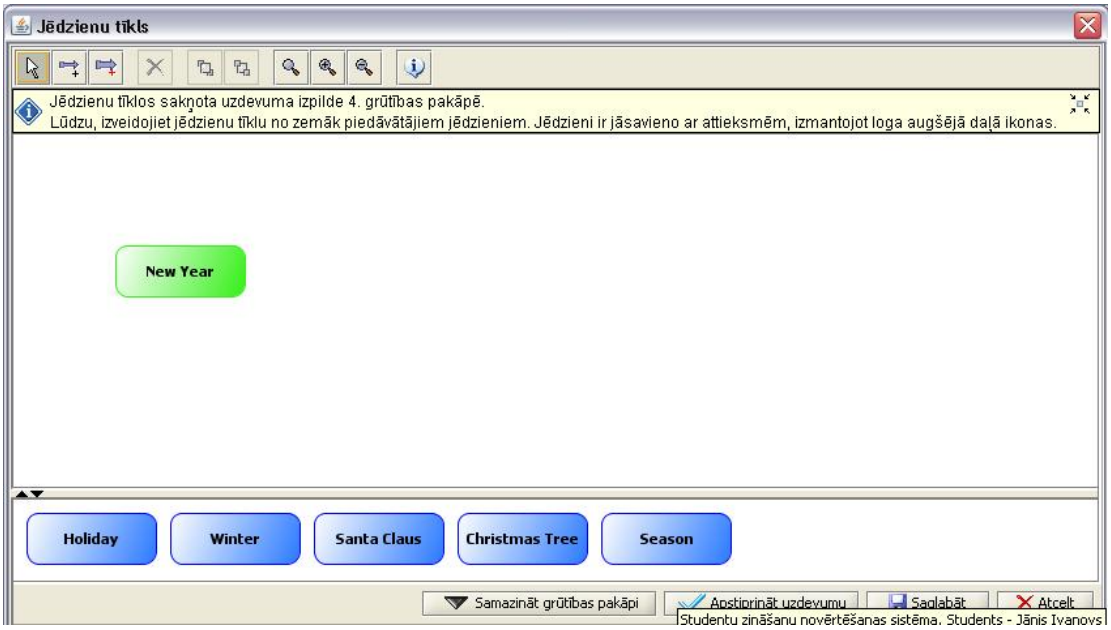

Figure 4: The screenshot of the learner's user interface for the "construct-a-map" task (the fourth degree of task difficulty)

The appearance of a particular concept map depends on the knowledge assessment stage. At the first stage the learner receives the task which has the teacher's pre-defined degree of difficulty (by ordinal number from Table 1). During the task performance the learner can ask to reduce the degree of its difficulty. In this case the transition is performed reducing the ordinal number of the task by 1 (Table 1). Of course, it is not valid for the first task. The learner can ask to reduce the degree of difficulty several times during the same stage. At the subsequent stages the degree of task difficulty depends on the learner's result at the previous stage. If the learner has reached the teacher's specified number of points without reducing the degree of difficulty of the original task, the degree of task difficulty at the next stage is increased by 1 (by ordinal number in Table 1). Otherwise, the degree of task difficulty remains the same. The process continues until the learner reaches the highest degree of task difficulty or completes the tasks of all stages.

Thus, eight transitions between tasks are implemented allowing the learner to find a task which is the most suitable for his/her knowledge level. Four transitions increase the degree of task difficulty and they are carried out after the receiving and analysis of the learner's solution, taking into account the score of the learner. This is a system's adaptive reaction to the learner's behavior. Other four transitions reduce the degree of task difficulty and they are carried out by the voluntary request from the learner during the task performance.

4.1.2 Additional insertion of concepts

This kind of help can be provided only in the previously specified "fill-in" tasks, where a teacher's created structure of the concept map and a set of concepts which must be inserted into it is given to the learner, that is, at the first, second and third difficulty degree. The main idea is the following. The learner chooses a concept from the set of concepts and asks the system to insert it into the right place (node) within the structure of the concept map. However, there can be two situations:

- the node of the chosen concept is free;
- the node of the chosen concept is occupied, that is, the learner has inserted into it an other concept.

In the first situation the system must insert the concept into the node and highlight it using another color. The concept must become unmovable, that is, it must hold its place in the task of the current and all other assessment stages.

The second situation can be further subdivided:

- the concept which is located in the node of the chosen concept does not have any relationships with other concepts. So, the system can remove it from the structure of the concept map and return it back to the set of concepts. After that the chosen concept must be

inserted into the node, the node must be highlighted using another color and the concept must become unmovable.

- the concept which is located in the node of the chosen concept has relationships with other concepts. In this case it is impossible to remove this concept from the structure of the concept map without breaking down learner's defined propositions which can be correct or partly correct. So, the system must highlight the node of the concept by a special color without insertion of the concept itself. Thus, the learner receives a possibility to change the location of his/her propositions and to insert the chosen concept into the highlighted node.

For this kind of help it is necessary to define a restriction on maximal number of concepts that can be inserted in this way in order the learner cannot complete the task using this method. Maximal number of concepts must be calculated taking into account the total number of concepts for the task of the current assessment stage. When the learner will use all possibilities to insert a concept this kind of help must become unavailable.

The described help does not provide any tutoring because it only reduces the total number of concepts that the learner must insert by him/herself.

4.1.3 Explanation of a concept

This kind of help can be provided for all previously described degrees of task difficulty (Table 1). The main idea is that the learner chooses a concept from the set of concepts and asks the system to explain it using one of the following types of explanations: definition of the concept, short description or example.

The explanation of a concept allows the usage of a student model for the provision of such type of explanations which are preferred by the learner or which the system recognizes as the most suitable for the learner. The initial type of explanations must be determined directly asking the learner to make his/her choice. However, that does not mean that the learner always will receive his/her chosen type of explanations. Firstly, the system must provide opportunities for the learner to use other explanation types if it is necessary. Secondly, the system must track the learner actions after the receiving a certain type of explanations and determine which of the types has the greatest contribution to the creation of right propositions. The last case must modify the student model.

This kind of help provides tutoring, as well. The reason is that the learner has a possibility to acquire knowledge about particular concepts. However, it demands additional workload from the teacher because it is necessary not only to define the concept map, but also to provide additional information about each concept: definition, short description and example.

4.2. Feedback

The feedback consists of numerical data, labeled learner’s concept map and possibility to check a proposition. The first two types of the feedback are given to the learner after the completion of the task, the last one is provided during solving of the task.

Numerical data includes:

- maximal score which the learner can obtain if the task is solved correctly;
- actual learner’s score;
- total time for the task completion if the teacher has defined it;
- time spent by the learner for the completion of the task.

The learner’s concept map after the completion of the task is marked with labels representing his/her received points for every relationship. The labels are in the form of “x of y” where x stands for points acquired by the learner and y for maximal possible points for this relationship. Relationships are also colored in different tones according to their correctness. The learner can acquire detailed information about each relationship by clicking on it using the mouse. In this case he/she sees contribution to the correctness of a relationship of all parts of a relationship: linking phrase, type, direction and placement of concepts.

Checking of a proposition can be provided at all previously described degrees of task difficulty (Table 1). The learner points out his/her created proposition (a pair of concepts) and the system checks its correctness. Moreover, this feedback can provide tutoring in case of incorrectness of a proposition by

presenting explanations of both concepts involved in the proposition. Explanations must be provided similarly to previously described in section 4.1.3.

The feedback must be provided in the form which shows contribution of each part of a relationship to the correctness of a proposition. However, it is necessary to define a restriction on maximal number of propositions which can be checked in this way. The number of allowed checking must be calculated taking into account the total number of propositions for the task of the current assessment stage. When the learner will use all possibilities to check propositions this kind of the feedback must become unavailable.

4.3. Summary

Table 2 specifies the defined kinds of possible help and feedback in the concept map based knowledge assessment system.

Table 2: Kinds of help and feedback and their characteristics

Type of support	Suitable types of tasks	Nature	Status
Help			
Changing of the degree of task difficulty	Both "fill-in" and "construct-a-map" tasks	Help providing, not tutoring	Already implemented
Additional insertion of concepts	Only "fill-in" tasks	Help providing, not tutoring	Not implemented yet
Explanation of a concept	Both "fill-in" and "construct-a-map" tasks	Help providing and tutoring	Not implemented yet
Feedback			
Numerical data	Both "fill-in" and "construct-a-map" tasks	Informative	Already implemented
Labeled learner's concept map	Both "fill-in" and "construct-a-map" tasks	Informative	Already implemented
Checking of a proposition	Both "fill-in" and "construct-a-map" tasks	Help providing, informative and tutoring	Not implemented yet

5. Conclusions and future work

The paper presents a research concerning learner's support in the concept map based knowledge assessment system. Three kinds of help, i.e., changing the degree of task difficulty, additional insertion of concepts and explanation of a concept, as well as types of feedback, i.e., numerical data, labeled learner's concept map and possibility to check a proposition, are described in-depth specifying suitable types of tasks, implementation mechanisms and nature. Moreover, the paper clearly states which types of learner's support have been already implemented in the system and which ones are in the stage of the implementation.

It is necessary to stress that identified types of help are learner-driven, that is, they are given only after the corresponding request from the learner. Moreover, some types of help are adaptive to the learner's characteristics. Firstly, the degree of task difficulty can be increased if the learner is completed the task reaching the teacher's specified number of points without reducing the degree of difficulty of the original task. Secondly, the learner can receive the type of explanations concerning a particular concept which corresponds to his/her preferences or which the system recognizes as the most contributing to the creation of correct propositions.

The future work has two main directions: 1) the implementation of kinds of learner's support which are not realized now, that is, additional insertion of concepts, explanation of a concept and checking of a proposition, and 2) the development of an evaluation mechanism which would take into account all types of help used by the learner in order to compare results of two learners one of whom used the help and other one, who did not use it.

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