Process Oriented Engineering Education Supported by Intelligent Knowledge Assessment System

A. Anohina, J. Grundspenkis
Department of Systems Theory and Design
Riga Technical University, Riga, Latvia
alleila@algs.lv, janis.grundspenkis@cs.rtu.lv

***Abstract* — Nowadays two aspects challenge engineering education. Firstly, knowledge society emerges as consequence of replacement of the industrial age by the information age. Knowledge has become the most important asset of people promoting their employability and competitiveness on a labour market. Secondly, constantly increasing influence and rapid growth of technology put forward demands for highly skilled and educated technical workforce. As a consequence, it causes changes in engineering education that should be related with the integration of knowledge management activities concerning diagnosis of misconceptions and missing knowledge. The paper presents an experience of knowledge management within a framework of process oriented learning where knowledge assessment is supported by means of concept map based intelligent system.**

Keywords – process oriented learning; knowledge assessment; intelligent system.

Introduction

During recent decades we are eye-witnesses of an epoch-making evolution from the industrial age to the information age. The characteristics of the industrial age are production and consumption of material things, hierarchical and centralized distribution processes, i.e. the application of fixed procedures that are compliant with standardized information schemes. By contrast, the information age which have started since last decades of the 20th century can be characterized by production and consumption of information, as well as interpretation of non-standardized information for problem solving and decision making.

The evolution towards the information age causes the rise of the information society in its diversity reality. The foundation of this society is “informationalism”, which means that the defining activities in all realms of human practice are based on information technology organized in information networks and captured around information processing [1]. Moreover, these changes cause emerging of new terms such as “knowledge work” and “knowledge society”. The essence of the knowledge work is turning of information into knowledge for the purposes of problem solving and decision making. In [2] it is noted that “knowledge has become increasingly relevant for organizations since the shift from an industrial economy based on assembly lines and hierarchical control to a global, decentralized, cooperative, innovative and information-driven economy”.

In this context it is worth to stress that new requirements and technologies influence a whole society of every country that is moving towards the information, and for knowledge society. The structural transformations towards informationalism cause changes in education institutions and processes. Requirements for specialists that are able not only to apply known technologies and decisions, but are innovative in all aspects of their activities and can turn information received into knowledge needed for effective actions are extremely high. Higher education institutions should adapt as quickly as possible to new demands of the labour market. That is the main reason why wide range of activities practically in all universities is carried out including activities in the relatively new field - the development of intelligent tutoring systems [3, 4, 5].

The paper is organized as follows. Section 1 defines process oriented learning and discusses knowledge management activities in the context of the learning process. Concept maps are briefly described in Section 2. Section 3 is devoted to the system functioning and its discriminative features in comparison with other tools. Section 4 gives attention to the results of the system testing. Finally, conclusions are presented and some directions for future work are outlined.

1 Process oriented learning and knowledge management

By process oriented learning we mean continuous management of learners' knowledge and improvement of educational process using for these purposes a systematic knowledge assessment. It is necessary for achievement of desirable characteristics of learners' knowledge which initially are defined by the teacher being based on overall aims of curriculum, employers' requirements and existing standards. 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 learning process improvement and knowledge management activities directed to the achievement of desirable knowledge characteristics. Knowledge management can be carried out both from the learner's side, and from the teacher's side. The teacher can manage learners' knowledge by changing teaching methods and learning content when deviations from desirable knowledge characteristics have been revealed after assessment of knowledge. Knowledge management from the learner's side means learner's self-activities directed towards filling blanks in knowledge. It is achievable through keeping track of his/her progress in learning by means of knowledge self-assessment.

It is obvious, that the greatest effect from the process oriented learning will be achieved, if both the teacher and the learner will carry out their knowledge management activities, thus, together directing educational process on achievement of desirable knowledge characteristics. Assessment becomes more as a tool of knowledge management and remediation instead of an instrument of knowledge control. However, it demands additional time and workload from the teacher's side. The teacher should carefully think over a learning course, dividing it in several logical stages, and provide means of knowledge assessment at the end of each stage. Exactly due to additional efforts the teacher does not usually put process oriented learning into practice. As a result, knowledge assessment very often is limited only with a final assessment, and knowledge self-assessment is ignored at all [6]. However, the use of computerized tools can help to solve these problems.

2 Concept maps

Concept mapping is an approach, which can be used "to externalize and make explicit the conceptual knowledge that student holds in a knowledge domain" [7]. Concept maps are a specific kind of a mental model which is visualized by nodes and arcs that represent concepts and conceptual links, respectively. Conceptual links can be represented with or without linking phrases written on them. Usually concept maps are organized in a hierarchical fashion [8].

Students by creation of concept maps during learning make sure that teaching material and the relations between studied concepts are correctly understood. In turn, concept maps assist the teacher in tracking of student understanding of teaching material and of student knowledge organization in the context of the learning course.

Concept maps allow to provide learners with tasks with different level of difficultness and to assess fourth and fifth levels of knowledge according with Bloom's taxonomy [10]. One of the ways to deal with different degrees of difficultness is to issue tasks with different degree of directedness [11]. Directedness is related with information provided to learners. Tasks can be divided in a subset of "fill-in tasks" where learners are provided with a blank structure of a map and lists of concepts and linking phrases, and in a subset of "construct a map tasks" where learners are free to make their choices.

The system described in this paper at the moment supports only one task: filling of a concept map structure. Two types of links are used. Important conceptual links show that relationships between the corresponding concepts are considered as important knowledge in a learning course. Less important conceptual links specify desirable knowledge. The linking phrases and direction are not used.

3 Basics of system functioning and implementation

The developed prototype of an intelligent assessment system based on concept maps allows to put into practice the notion of process oriented learning providing all necessary functions both for the teacher and for the learner (Table 1).

Table 1 – System's functions for the teacher and the learner

System's user	Functions provided by the system
Teacher	• providing of information on learning courses taught by the teacher and on learners studying a particular learning course, as well as about the number of concept maps within a learning course, the maximum score, the publication status and the date of a particular concept map • setting/ unsetting of publication date of a particular concept map • tools for developing concept maps such as concept inserting and linking, setting of publication date, concept map annotation, saving and zooming • tools for editing and deleting concept maps • tools for examining of learner-completed concept maps and score, as well as for deleting the learners' results • different possibilities for information searching and retrieval
Learner	• providing of information on learning courses studied by the learner and on concept maps within a learning course (stage, status of publication, and learner's score) • tools for filling concept maps provided by the teacher such as concept adding, removing and solution submission • tools for viewing feedback after the learner has submitted his/her solution

The functions described in Table 1 comprise the teacher's module and the learner's modules of the system's architecture respectively. The third module allows the administrator to manage data about learners and groups of learners, teachers and learning courses. The modules interact by sharing a 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. The modules and their interacting are described in [12].

As the main purpose of the system is to support process oriented learning it provides further extension of a concept map created for the first stage of the learning course. The procedure is the following. The teacher includes the concepts taught to learners at the first stage of the learning course and relationships between them into the first concept map of the learning course. At the second stage he/she extends the initial concept map by adding new concepts, but doesn't change the relationships among already existing concepts. Thus, a concept map of the last stage displays all concepts in the learning course and relationships between them.

Few other assessment tools based on concept maps are known at the moment. One of them is COMPASS [13]. It is a Web-based system that provides assessment of the learners' knowledge level through various concept mapping tasks and supports the learning process generating the informative and tutoring feedback after the analysis of a learner's concept map. The other example is described in [14]. It has two versions: one of them supports the task of filling in the blanks of incomplete structure of a concept map, other offers an opportunity to freely construct a concept map. Both versions provide evaluation and hint functions. However, the system described in this paper has two discriminative features in comparison with the mentioned tools. Both known systems consider assessment as a discrete event, while the developed system supports process oriented learning and allows the teacher to extend the initially created concept map for the new stage of assessment. The second unique feature is an algorithm that compares the teacher's and learner's concept maps and is sensitive to the arrangement and coherence of concepts [15].

The system is a Web-based application developed using the following tools: Borland JBuilder 9.0., JGraph, and PostgreSQL DBMS 8.0.3. The architecture of the system from the point of view of used technologies is described in [12].

4 Testing results

The system has been tested on five engineering courses. In the autumn of 2005 the testing took place on the learning courses "Information System Analyses and Development" and "Modelling and Formal Specification" in Vidzeme University College (Latvia), as well as on the learning course "Systems Theory Methods" in Riga Technical University (Latvia). The testing on the learning courses "Fundamentals of Artificial Intelligence" and "Introduction to Artificial Intelligence" passed in Riga Technical University in spring of 2006. Eighty two students were involved in the testing process. After testing students were asked to complete a questionnaire. The 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 seventy four questionnaires have been processed. The testing statistics is displayed in Table 2.

Let's consider some important questions and students' answers.

Whether do you understand essence of concept maps? The five answers were offered to students: *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, and *E*. Other answer. Fig. 1 (a) shows that the majority of students understood essence of concept maps, as well as they positively evaluated the offered idea of knowledge assessment.

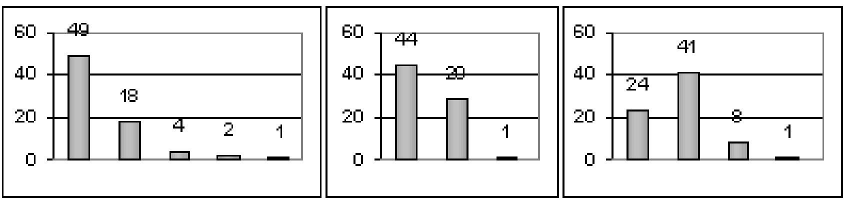
Table 2 – Testing statistics

Time	Learning course	Number of students involved in testing	Number of questionnaires received
Autumn 2005	Information System Analyses and Development	14	12
	Modelling and Formal Specification	33	26
	Systems Theory Methods	17	15
Spring 2006	Fundamentals of Artificial Intelligence	19	15
	Introduction to Artificial Intelligence	9	6
	Totally	**82**	**74**

Whether the filling of concept maps has helped you to understand teaching material better? The following answers were offered: *A*. Yes, *B*. No, and *C*. Other answer. Fig. 1(b) displays their distribution. The analysis of answers revealed that concept maps activate thinking and help to arrange the mastered concepts.

Would you like to use such method of knowledge assessment also in other learning courses? The offered answers were the following: *A*. Yes, *B*. Possibly, *C*. No, and *D*. Other answer. The majority of students agreed to use concept maps in other learning courses (Fig. 1 (c)), but only under condition that both the approach to knowledge assessment, and functionality of the system will be improved in future.

The testing results have confirmed system effectiveness for continuous assessment of learners' knowledge. Moreover, the positive evaluation of the chosen method of knowledge assessment and the developed system has been received from the students' side. The example from the system's testing in the learning course "Systems Theory Methods" is described in [12]. The analysis of questionnaires from the autumn testing is described in details in [16].



(a) (b) (c)

Figure 1 – Distribution of the student answers

5 Conclusions and future work

The main advantages of the developed system are the Web-based application that allow to use it from any remote location with Internet connection, the clear graphical user interface both for learners and teachers, the support of process oriented learning and intelligent algorithm for comparison of learner's and teacher's concept maps.

Two main directions of future work are chosen as priors. One of them is related with the use of ontologies for deepening knowledge assessment and for generating the recommendation concerning learning material which a learner should review for filling blanks in his/her knowledge. Some initial ideas are discussed in [16]. The second direction concerns concept maps based adaptive knowledge assessment which will allow to present learners with tasks appropriate to their knowledge level in order to acquire more accurate conclusions about the actual knowledge level of a learner. Two possibilities for adaptive knowledge assessment are described in [15].

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