ADAPTATION OF INTELLIGENT KNOWLEDGE ASSESSMENT SYSTEM BASED ON LEARNER'S MODEL

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Abstract. The Department of Systems Theory and Design of the Faculty of Computer Science and Information Technology of Riga Technical University has been developing the concept map based intelligent knowledge assessment system IKAS already for five years. The paper gives the outline of adaptation mechanism which is under the development and will be integrated with IKAS. The adaptation mechanism is based on learners' psychological characteristics. Learning styles have been chosen as the most widely used psychological characteristic. Several models of learning styles are overviewed and the Felder-Silverman model has been chosen as the most appropriate for IKAS. For explanation why more flexible adaptation mechanism is needed in IKAS its architecture and functionality is presented. The conception of the design of adaptation mechanism which will be implemented in a user modeling shell AGENT-UM is described.

Keywords: adaptation, user modeling, learning style, intelligent knowledge assessment system, production rules

1 Introduction

Results of many conducted researches show that e-learning systems which incorporate adaptation to the learner are more efficient and useful in comparison with systems which have no adaptation features [8, 17]. Adaptive e-learning systems are capable of delivering personalized study materials. In addition, those systems could choice presentation format which is most suitable for each particular learner. Therefore, adaptive e-learning systems become more and more popular nowadays and developers try to incorporate adaptation functionality in almost any new e-learning systems.

One way how to provide adaptation in the e-learning system is the use of a learner's model. The learner's model is a record that reflects specific characteristics of the learner that uses e-learning system. Examples of data that are hold in the learner's model are the general information about the student (such as the username, the profession), student's knowledge level in specific area and student's mistakes, physiological and psychological characteristics of the student [7, 25].

This paper is focused on psychological part of the learner's model, because psychological characteristics of the learner significantly influence a study process [7]. Design of adaptation mechanism based on learner's psychological characteristics is presented in this paper.

Adaptation mechanism is designed for the concept map based intelligent knowledge assessment system IKAS. The system which has been developed by researchers from Riga Technical University during last four years has a couple of areas where adaptation based on learner's psychological characteristics could be successfully applied in order to enhance system's functionality [1]. At present those areas include selection of appropriate type of task for each particular learner and selection of the most suitable type of help for each learner.

The paper is organized as follows. Section 2 gives a brief overview of learner's most significant psychological characteristics that influences a study process. In Section 3 architecture and functionality of IKAS is described. In Section 4 design of adaptation mechanism based on learner's psychological characteristics for IKAS is presented. At the end of the paper conclusions are given and future work is discussed.

2 Overview of learner's psychological characteristics

Different factors that influence learning process are considered in a student's model. Those are demographic factors, professional factors, ability and proficiency, knowledge level, physiological factors, emotional state, mental state and others [7, 14, 25]. Among those factors are learner's psychological characteristics that attracted much attention of developers of e-learning systems in the recent years [4, 7, 8, 12, 17, 18].

Learner's psychological characteristics related mainly to human mind and memory. Unique set of those characteristics for each learner results in individual differences of information perceiving, processing and storing [24].

There is plenty psychological characteristics of the learners used till now. Most known characteristics are learner's intellectual abilities (abilities to learn), cognitive style, learning style, temper, brain dominance [7,

14]. Examples of specific characteristics are inductive reasoning skills, working memory capacity, procedural learning skills, information processing speed, associative learning skills [19].

Review of available literature shows that the most widely used psychological characteristic of a learner is his/her learning style. A learning style is defined as a characteristic of cognitive, affective, and psychological behaviour that serves as a relatively stable indicator of how a learner perceives, interacts with, and responds to the learning environment [5]. Study of learning styles started in 1970s [24] and many learning style models have been developed till now. A learning style model divides learners into several categories depending on psychological characteristics and defines effective teaching strategy for each category. Most known learning style models are Myers-Briggs model [3], Kolb model [13, 20, 24], Honey-Mumford model [3, 20], Felder-Silverman model [3, 9, 20, 22], Grasha-Riechman model [3]. The list of dimensions within mentioned learning style models is given in Table 1.

Table 1. Learning styles proposed by some known models

Learning style model	Dimensions within the model
Kolb model	Converger/Diverger
	Assimilator/Accomodator
Honey-Mumford model	Activist/Reflector
	Theorist/Pragmatist
Felder-Silverman model	Sensory/Intuitive
	Visual/Verbal
	Inductive/Deductive
	Active/Reflective
	Sequental/Global
Grasha-Riechman model	Competitive/Collaborative
	Avoidant/Participant
	Dependent/Independent
Myers-Briggs model	Extravert/Introvert
	Intuitive/Sensing
	Feeling/Thinking
	Judging/Perceiving

Kolb's model was the first learning styles model. The model was developed by David Kolb in 1984 and the model is based on four-stage learning cycle. According to Kolb's theory each learner goes through four stages during learning process – concrete experience, reflective observation, abstract conceptualization and active experimentation. However, Kolb's experimentations revealed that despite of fact that a learner goes thorough all four stages two of these stages stay dominant for each individual learner. Based on the results Kolb created a learning style model. In his model "Converger" uses abstract conceptualization and active experimentation, "Diverger" tends to concrete experience and reflective observation, "Assimilator" uses reflective observation and abstract conceptualization and "Accomodator" uses concrete experience and active experimentation.

Honey – Mumford is the second learning styles model that was developed in 1986. The model is also based on Kolb's theory about four-stage learning process. Four learning styles that presents in the model are "Activist", "Reflector", "Theorist" and "Pragmatist".

Grasha-Riechman and Myears-Briggs are other rather popular learning styles models that use their own theories (different from Kolb's theory) for identifying learning styles. There are 6 learning styles in Grasha-Riechman model and 8 learning styles in Myears-Briggs model

It is worth to add that some learning style models have also questionnaires that could be used to determine learning style of a particular learner. Those questionnaires could be easily built into the e-learning system and it become possible to use learning styles afterwards for adaptation purposes. Some practical examples of use of learning styles in e-learning systems are described below.

In Arthur system [8] course materials could be presented in three different forms – audio, visual and text. Each student receives course materials in a format that is the most suitable for him. For example, a student with verbal learning style receives course materials in textual format; in turn, for visual student materials in visual format are presented. Thus, correspondence between learning style and teaching style is achieved.

The Feedback System [18] provides personalized feedback for each learner taking into account his/her learning style. The following types of feedback are available in the system – definition, example, question, scaffold, picture, relationships, application and exercise. For example, verbal student will receive feedback in a form of definitions, visual student will receive feedback in a form of pictures and active student will receive feedback in a form of exercises.

Examples of other e-learning systems in which adaptation based on learning styles is used are the Multimedia System [17], the Concept Map Based System [4], Lecompas5 [12].

Our analysis of learning style models shows that the most widely used model nowadays is Felder-Silverman learning style model [9]. The model was developed by Richard Felder and Linda Silverman in 1988. The model is popular due to three reasons. Firstly, the model has many dimensions, and therefore, more accurate classifications of learners could be made. Secondly, the model defines a teaching style for each learning style within the model, and thirdly, the model has a well structured and easy to use questionnaire to determine learning styles. Therefore, Felder-Silverman learning style model is used in adaptation mechanisms in IKAS as well. Description of learning styles according to Felder-Silverman model is given in Table 2. More detailed description of this model could be found in [3, 20, 22].

Table 2. Felder-Silverman learning style model [20]

Learning style	Description
Sensory	Concrete, pragmatic, focused on facts and procedures
Intuitive	Conceptual, innovative, focused on theory
Visual	Give preferences to pictures, diagrams
Verbal	Give preferences to texts or audio
Inductive	Prefer explanation from concrete to general
Deductive	Prefer explanation from general to specific
Active	Learn through experimentation and collaboration
Reflective	Learn through thinking things while staying alone
Sequential	Learn sequentially in a small steps
Global	Learn in a non-linear manner jumping from one topic to other

Felder-Solomon questionnaire [6] was designed in order to identify student's learning styles according to Felder-Silverman learning style model. Using the questionnaire learning styles in the following four dimensions could be identified – sensory/intuitive, visual/verbal, active/reflective, sequential/global. The questionnaire contains 44 questions and it is available online.

For purposes of adaptation mechanism under consideration Felder-Solomon questionnaire was modified slightly. Changes made in the questionnaire are described in Section 4.

3 Architecture and functionality of the concept map based intelligent knowledge assessment system

The system, for which purposes an adaptation mechanism is intended to be developed, is the concept map based intelligent knowledge assessment system (IKAS). This system has been developed by the researchers from the Department of Systems Theory and Design of the Faculty of Computer Science and Information Technology of Riga Technical University. The system allows the teacher to assess student's knowledge regularly, that is, at each stage of the study course, and to use assessment results for the analysis and the improvement of learning content and teaching methods. At the same time the student can use the system for knowledge self-assessment in order to control and to keep track of his/her own learning progress.

The developed IKAS consists of three modules. The administrator's module allows managing data about users (learners and teachers) and study courses providing functions of data input, editing, and deleting. The teacher's module supports teachers in construction of concept maps. The main functions of this module are the following: editing and deleting of concept maps, evaluation of learners' completed concept maps and assigning the scores which characterize the level of correctness of learners' concept maps. The learner's module includes tools for completion of concept maps given by a teacher and for viewing feedback after the solution is submitted. The modules interact sharing a common database where data about teachers and their courses, learners, teacher created and learners' completed concept maps, as well as learners' final scores are stored.

IKAS supports the following usage scenario. A teacher divides a study course into N stages and defines all concepts and relationships between them. Using the system's graphical user interface, a teacher prepares concept maps for each stage. The system supports teacher actions for drawing concept maps on the working surface. During knowledge assessment or self-assessment students get a task (a concept map) that corresponds to the current stage of learning process (Figure 1). After finishing the task, a student confirms his/her solution and the system compares concept maps of the student and the teacher. The final score and the student's concept map are stored into the database, and a student receives feedback about correctness of his/her solution.

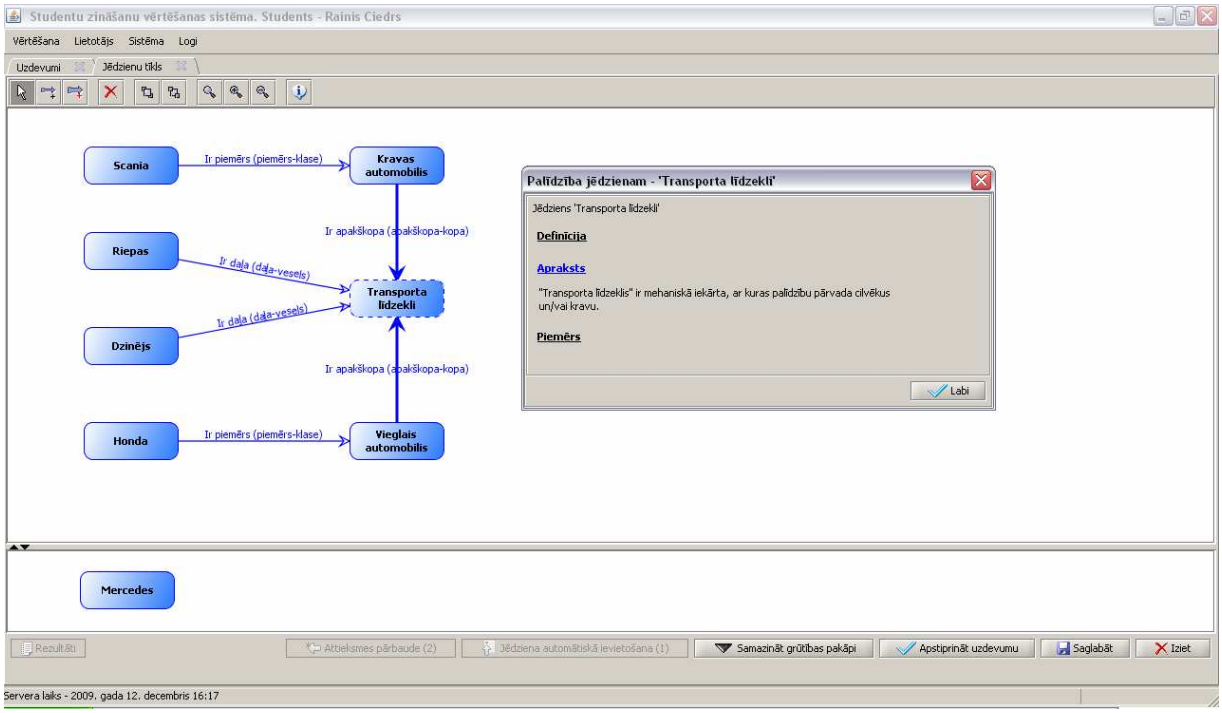

Figure 1. IKAS working surface

More detailed description of the IKAS could be found in [1, 10, 16, 23].

The system has already reached the certain level of maturity and has been used successfully in practice. Nevertheless future enhancement of the system should be done in order to make it even more useful. For example, the system has minimal functionality in adapting to a user at present. There are at least two ways how adaptation mechanism based on learning styles could be applied in IKAS. Firstly, a learning style could be used to select appropriate type of task for each particular learner. There are two types of tasks currently implemented – "fill-in-the-map" tasks where the learner should fill the given skeleton of a concept map with missing information (the learner should either give names to concepts or to links or to both) and "construct-the-map" tasks where the learner creates a concept map by himself using given lists of concepts and links [2]. At present the teacher choose what type of task will be given to all students. Our aim is to use learning styles in order to provide for each learner the type of task that bests suits him/her.

Secondly, learning styles could be used to select appropriate type of help for each learner. There is a possibility for the learner to get one of three types of help for unknown concepts – definition (formal definition of the concept), explanation (free text explanation of the concept) and example (visual example of use of the concept) [2]. In the system's current version the learner defines manually what type of help will be used for all unknown concepts. Our aim is on the basis of learner's learning styles provide the type of help that bests suits him/her.

The next section describes usage of learning styles in IKAS in more details.

4 Design of adaptation mechanism

Adaptation mechanism which we design for IKAS will be presented in a form of user modelling shell (UMS) [15]. UMS is an external system that is used for learner's modelling purposes. UMS gathers and stores information about learner's knowledge, personal characteristics, goals and preferences, thus assisting the target e-learning system in adapting to users.

High level design of a user modelling shell AGENT-UM for IKAS was already presented in [15]. The AGENT-UM is an external agent-based user modelling shell that is supposed to supply IKAS with user modelling functionality. The AGENT-UM was designed to provide the following services for IKAS – get general data about a learner from his/her answers in questionnaires, infer assumptions about a learner based on his/her interaction with IKAS, infer additional assumptions based on initial assumptions, represent and store all student's data in a student model, supply IKAS with current information about a learner. Thus, application of the AGENT-UM in general could assist IKAS much in modelling a learner and in adapting the learning environment for each individual learner needs.

In this article we describe in details use of learning styles in AGENT-UM. We believe that incorporation of learning styles will make the first significant step toward realization of adaptive behaviour of IKAS.

Figure 2 demonstrates the architecture of adaptation mechanism (AM) for IKAS based on learning styles.

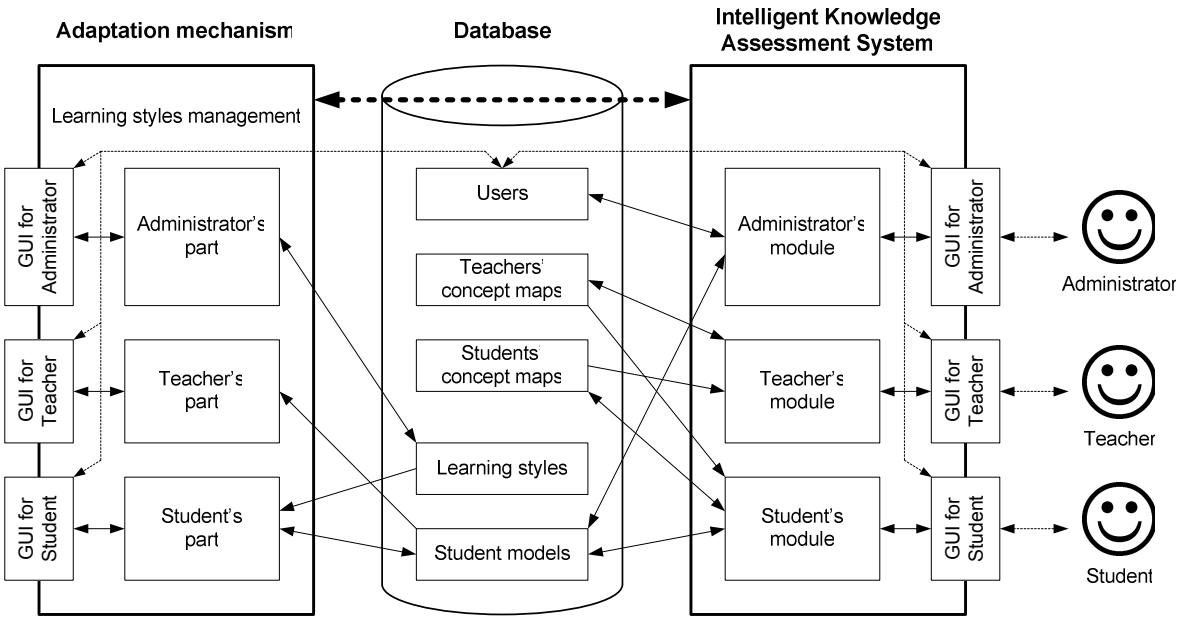

Figure 2. Architecture of adaptation mechanisms for IKAS

AM consists of three parts. The administrator's part is used for editing description of learning styles. The teacher's part is used for viewing students' models (learning styles). The student's part is used for filling learning styles questionnaires and for viewing and editing personal learning styles.

AM and IKAS have the common database. Two shared storages are Users and Student models. Users that are managed from IKAS are common for both systems. It means that users that are authorized to use IKAS have access to AM as well. Need to point, that AM has no separate login functionality. In order to access AM user should login into IKAS first and then switch to AM. Switching is performed automatically without need to reenter credentials and with saving initial login role (for example, if the user is logged into IKAS as a Teacher, he/she will be switched to AM also as a Teacher).

The storage "Student models" is managed by both sides – AM and IKAS. IKAS fills a student model with the following data – the general information about the student (name, surname, student card number, email, group, login name, password, role), student's preferences (GUI language, themes, colors, preffered type of help), student's results in knowledge assessment and student's mistakes (wrong edges). AM adds appropriate learning style to a student model. Content of a full student model that is used by IKAS to make necessary adaptation of learning environment is shown in Figure 3.

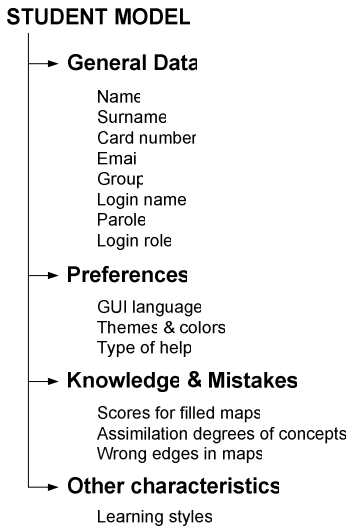

Figure 3. Structure of a student model used in IKAS

AM is used by three types of users. Functions that are available for each type of user are summarized in Table 3.

Table 3. Functions available in AM

Type of user	Available function
Administrator	Adding description of learning styles
	Setting a default learning style
Teacher	Viewing learning style of a specific student
	Viewing aggregate learning style of a group of students
Student	Filling questionnaire about learning style
	Viewing personal learning style
	Modifying personal learning style

Let's describe functions available in AM in more details. Administrator is responsible for adding description of learning styles in AM. Description of learning styles will be used by students and teachers afterwards like a glossary that could help in interpreting students' models. Administrator will set a default learning style as well. A default learning style will be attached to those learners who don't fill questionnaire about learning styles. Research on learning styles shows that a dominant learning style exists for modern learners [17]. Modern students are active (they like real word problem solving), visual (they prefer visual presentation of information) and global (they study in non-linear manner jumping constantly from one course subject to other subjects). This dominant learning style will be set as a default learning style in AM.

Teacher in AM could view either a learning style of a specific learner or an aggregate learning style of a group of students. Inspection of the learning style of a specific learner could help a teacher to choose teaching methods that are the most suitable for that particular learner. Those teaching methods could be used by a teacher during private consultations with that learner. In turn, inspection of an aggregate learning style for a group of students could help a teacher to understand what type of learning styles dominates in the group and what teaching methods are the most suitable for the whole group. Those teaching methods could be used by a teacher in a classroom while working with a group of students.

In order to get a personal learning style the student must fill modified Felder-Solomon questionnaire about learning styles. After filling the questionnaire the student will be able to see his profile with dominant learning styles. Textual explanations to each dimension will be given as well in order to provide the possibility for a student to understand better his/her learning style. In addition, the student will be able to modify his/her learning style if he/she concludes that values for some dimensions are set wrong. Research on learning styles shows that sometimes questions from questionnaires could be wrongly interpreted by students [21]. This results in incorrect identification of learning style for a particular learner. Therefore, it is strongly recommended to give opportunity to the student to set his/her learning style by him-/herself based on description of learning styles.

As it was mentioned before the original Felder-Solomon questionnaire was modified taking into account specific of AM for IKAS. Felder-Solomon questionnaire in its original version contains 44 questions and allows identifying four dimensions of learning styles – sensory/intuitive, visual/verbal, active/reflective, sequential/global. For purposes of AM only three dimensions are used – visual/verbal, sequential/global and active/reflective. Dimension "Sensory/Intuitive" is not used in AM because learner's characteristics that come from this dimension (see Table 2) could not be applied for adaptation of IKAS at present. In addition, eleven questions that belong to "Sensory/Intuitive" dimension could be removed from questionnaire. Thus, it will require for learner to answer 33 questions to identify dominant learning styles in three remaining dimensions.

Dimension "Visual/Verbal" is used to determine type of help (definition, explanation or example) that is the most suitable for a learner. Dimension "Sequential/Global" is used to determine type of task ("fill-in-the-map" task or "construct-the-map" task) that is the most suitable for a learner. Dimension "Active/Reflective" is supposed to be used for determination of appropriateness of using concept maps for knowledge acquisition. Results of recent research in learning styles shows [4, 17] that modern students are active students who like constructive approach to knowledge acquisition. Therefore, one of methods that could satisfy requirements of modern learners to knowledge acquisition is the use of concept maps. Using the results of two questionnaires – identification of students' learning styles in "Active/Reflective" dimension and determination of satisfaction of using concept maps for knowledge assessment – we could conclude afterwards whether active students are dominant or not and whether concept maps are accepted by active students as a good tool for knowledge acquisition.

Let's describe in more details how learning styles in "Visual/Verbal" and "Sequential/Global" dimensions are supposed to be used for adaptation purposes in IKAS. In [11] the idea of using production rules for adaptation based on learning styles was proposed. Therefore, the following production rules could be generated for adaptation of IKAS:

Rule 1: *IF Learner = "Visual" THEN TypeOfHelp= "Example"*

Rule 2: *IF Learner = "Verbal" THEN (TypeOfHelp= "Definition") or (TypeOfHelp= "Explanation")*
Rule 3: *IF Learner = "Sequential" THEN TypeOfTask= "Construct"*
Rule 4: *IF Learner = "Global" THEN TypeOfTask= "Fill-in"*

Rule 1 says that if a learner belongs to a visual type of learners then visual examples about the usage of concept will be presented to the learner when he/she asks for help. Rule 2 says that if a learner belongs to a verbal type of learners then either definition or explanation will be provided for problematic concepts for this learner. Definition will have a priority one. If for a particular concept a definition is not given then an explanation will be offered for that concept. Rule 3 says that if a learner belongs to a sequential type of learners then "construct-the-map" type of task will be given to him/her. "Construct-the-map" type of task allows learner to control the process of creation of concept map from the very beginning. A learner could sequentially and incrementally construct the concept map placing the most important concepts first and then adding less relevant concepts to the map. Rule 4 says that if a learner belongs to a global type of learners then "fill-in-the-map" type of task will be given to him/her. In this type of task a learner should place missing information (concepts or links) on the map. "Fill-in-the-map" task require from a learner a global vision of the subject. A learner could be able to see "the whole picture" in order to deal successfully with that type of task.

At the end let's describe scenario of using adaptation mechanisms with IKAS. When student login into IKAS for the first time he is kindly invited to go to AM and fill questionnaire about his learning style model. If a learner ignores invitation a default learning style model (visual-global-active) is set for that learner. If a learner accepts invitation he/she is directed to AM where he/she fills Felder-Solomon questionnaire first and then views the results on his/her dominant learning styles. A learner may correct learning styles manually if he/she concludes that learning styles set after filling questionnaires were incorrect. After that a learner switches back to IKAS and starts with knowledge assessment routines. At the same time IKAS reads learning styles of a learner and adapts immediately content and presentation of assessment tasks. Thus, adaptation of e-learning environment is achieved.

5 Conclusions and future works

In this paper a conception of adaptation mechanism (AM) based on learning styles is presented. The adaptation mechanism is designed for the concept map based intelligent knowledge assessment system (IKAS) that has been developed by researchers from Riga Technical University and has been already used successfully in practice. Proposed AM is a part of user modeling functionality required for adaptation of IKAS. AM will be used for adaptive selection of type of tasks and type of help for each specific learner.

The first version of AM will offer the following functionality to its users. Students in AM will be able fill questionnaire on learning styles and inspect and modify their learning style models afterwards. Teachers will be able to inspect individual and group learning style models in order to see the dominant learning styles for an individual or a group.

Future enhancement of the adaptation mechanism could be related with implementation of teaching styles into AM. It would be useful to have a library of teaching styles and to display appropriate teaching style next to learning style models. For example, teacher could look at a group learning style model and read immediately about the teaching style which is recommended for that particular group. This will make adaptation mechanisms even more useful.

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