Learner Model's Utilization in the e-Learning Environments

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Abstract. In the field of personalized systems big role is granted to the adaptive e-learning environments. The task of these systems is very important and complicated. With their participation the learner gains exactly the knowledge he needs most, and the system adapts to user needs, expectations and his individual features. In this kind of systems information about learner is saved in the learner model also known as the user model and student model. For the system to be able to perceive and analyze user activities correctly, is necessary to define what kind of information about the learner has to be saved. The article gives an overview about already existing learner models, their utilization methods and also it offers their comparison according to various criteria.

Keywords. E-learning, adaptation, learner model

Introduction

When the tempo of life becomes more and more intensive, the necessity of the new and effective solutions in different scopes including education arises. One of the most actual tasks for educational quality improvement is the utilization of an e-learning system. One part of such learning environments is passive and used only to supply users with static content and to ensure identical system reactions to the users' activities. The other part of the learning environments adapts to the user as a personality by offering learning in the most appropriate way for him. The abovementioned environments are called adaptive learning environments (ALE). One of their tasks is to find out user's personal qualities that influence his learning process and his knowledge level in certain moment of time to offer a learner certain learning content and learning methods, which are the most appropriate exactly for him, to ensure the best learning results. Several adaptive systems are offered in the works of Hauger and Köck [14].

The role of adaptive systems nowadays gets bigger every year. This type of systems can help to acquire knowledge at schools, universities and other kind of learning institutions. ALEs can be used for the student teaching in schools as a secondary instrument to acquire fundamental and additional knowledge, but for students in universities they serve as a primary instrument for acquiring new knowledge and organizing their study plan. For the lifelong learning of adults ALE can serve as an instrument for gaining new knowledge and raising professional qualification. ALE can be used also to ensure learning interaction with already existing learning environments. For example, ALE cooperating with popular social networks

can offer some specific knowledge for certain user group. Also, for the children of preschool age adaptive learning system can be used as an instrument of gaining basic knowledge that would be necessary at school.

The aim of the work is to explore structure models of the adaptive systems (including learning systems), especially – user model and its components, and to explore data which are already included in user model and select the most common used data which would be useful for creating adaptive system based on user model.

This work is written based on scientific articles that reflect the newest trends in formatting and utilization of the learner model. The most-cited literature has been analyzed, as well as the newest review articles about learner model and papers that describe already realized adaptive system examples.

Alenka Kavcic [16] points out several most relevant questions, which should be considered when creating a user model: a) what kind of information must be included in the user model, b) how to gain this information, c) how to represent information about a user in the system, and d) how to create and restore a user model.

The first section of this paper gives an overview of the models used in the adaptation process, user profiles and explanation of the learner model concept, their common and different features, the ways to obtain profile data and its utilization for creating a user model. In the second section an overview of the data included into the user model of an adaptive learning system, and the data included into the learner model are summarized. Also, a definition of this data is given. In the end of the section LM is offered a table that summarizes employed data with the aim to obtain the most significant data that must be included into learner model. The third section describes the creating stages and construction techniques of the user model of an adaptive system. The paper ends with conclusions on the accomplished overview of the learner model utilization in adaptive systems.

1. Learner Model Essence

1.1. A Review of the Models Necessary for Adaptation

Adaptation in the learning environments is based in the well-organized models and processes. Data that describes knowledge in the system and learner behavior are extensive. When exploring scientific articles [8, 9, 16, 24, 28, 33] on different types of adaptive systems, one may conclude that they are based on the three main models: a domain model, a user model and an adaptive model.

A domain model includes two main parts: content or system offered domain knowledge, and a supply system for this content. In [9] authors points out that a domain model works like a data repository, which consist of topics, content, pages or nodes and navigation links that connect the represented data design structure. Domain knowledge consists of knowledge basic elements such as concepts, topics, knowledge items, learning goals, learning results. Domain delivery system must support all course types and manage to adapt to the different requirements for the course content.

An adaptive system adapts to users' needs that is why one more important component of these systems is a user model. In the learning systems it is also called a student model or *learner model* (LM). In [26] authors call a LM the key and core of the adaptive system. The learner model keeps all information about the learner, i. e.,

personal information, his knowledge, skills, and behavior in the system. Intelligent Tutoring Systems (ITS) learner model is also called a student model [35].

Domain and learner models are connected with the help of an adaptive model. *An adaptive model* ensures the application of the system flexibility theory by combining domain and learner models [9]. By analyzing learner model student needs are gained, and knowledge representative nodes are offered to him the system. These nodes can be classified by knowledge type as follows: basic knowledge (includes knowledge about definitions, formulas, etc.), procedural knowledge (solves relationship between stages), and conceptual knowledge (refers to relationship between concepts by developing bigger common scene) [39]. In widely spread Adaptive Hypermedia Systems (AHS) an adaptive model is also called an interaction model [11, 27]. In the Intelligent Tutoring Systems (ITS) adaptive model functions are fulfilled by pedagogical model [35].

Depending on the adaptive system type, in addition to the previously mentioned models, there can also be other models, which ensure the system supplied services. AHS systems have also the fourth model: media model [3, 28]. Along with the learner model there is also a group model [33], which is similar to learner model but is filled dynamically and is based on learner group identification after some common features and behavior.

1.2. Basics of Learner Model Creation – A User Profile

To make an adaptive system, which could respond exactly how the user wants, information about the user is needed. The easiest way how to obtain information about the system user is to use his data from the user profile.

In the profile static (constant) information about the user without any additional description or interpretation is kept [30]. Profile data contains learner personal data as well as data on his individual features and habits. User data in the profile is represented as attribute pairs – key-value. User model creation, modification and maintenance process is called user profiling. A system should provide profile attribute initialization, adding, saving, modification, deletion and extraction.

Unlike the profile, a *user model* is an abstract representation of the system user [23], where, in addition to the profile data, some specific information about the person is included. For example, in [27] a learner model consists of the domain independent data that consists of Generic profile, Psychological profile, and domain-dependent data. The user model contains all information that the system has on the user and maintains live user accounts in the system [33]. In the general case, the profile concept is narrower than the user model concept. In a simplified case, they can coincide [Kules2000]. User profile data can serve as the base for the creation of the user model. A profile keeps static information, but the user model keeps both – static and dynamic information.

1.3. Obtaining Data for the Learner Model

When the user interacts with the system for the first time, a user profile that contains the basic information about the user is being created in the system. Information in the user profile can be obtained in similar ways.

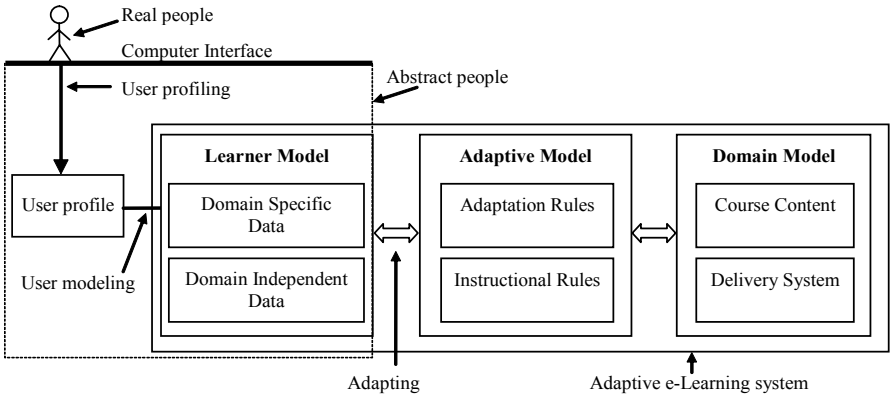

Fig. 1. Adaptive e-Learning system scheme

There are several approaches to create a user profile:

a) A user creates his profile on his own, based on his interests [25]. A part of the user profile information can be obtained directly from the user registration form or questionnaires: for instance, birth date and gender. For example, in [7] EASEL project with the help of AHS Questionnaire Servlet the system asks the user some simple questions to gain data about visual, audio, read/write and kinesthetic attributes. However, such information as user preferences is very hard to gain and that is why they must be taken from the user interaction with the system.

b) A system creates a profile by itself by collecting necessary information about the user indirectly, for instance, from activity log files, where it is written what a user has chosen and what actions he has accomplished in the system [25].

c) Mixed approach, when one part of information is input by the user, but the second part of the information the system gains indirectly [25].

d) ALE integration with other informational systems with user data import from some other system:

- From the informational system (IS) which ALE is related to. For example, ALE has "cooperation" with administrative system of the educational institution, which contains general information about an IS user. IS imports user data into the adaptive learning environment and ALE uses this data as an entrance data to create the first notion about the learner. When gaining data from IS to the ALE in this way, such information as the type of knowledge student must acquire (for example, registration to the certain course) is also often indicated [35].
- From other type of systems with user registration. Nowadays social networks where people spend a lot of time (for example, facebook.com, draugiem.lv) have become widely used and popular. Versatile information about the user is saved there, i.e., his personal data, interests, skills of communication with people, activities in groups, etc. From that kind of systems, which widely characterize its user, data can be taken and integrated into united adaptive learning system user model. In this case, it would be important to anticipate both system cooperation opportunities.

e) Gaining data from ePortfolio: a web-based electronic material resource, which contains material collection that is made and managed by user [5, 42]. ePortfolio also indicates the user learning or professional growth. Fsor example, in [34] a research

about ePortolio integration with Learning Management System (LMS) Moodle is described.

2. Learner Model Data

2.1. Learner Model Data Types

Information included in the user model can be grouped differently: (a) by data dependence from the subject, (b) by data obtaining type, (c) by data availability for the learner, and (d) by data life-cycle in the user model.

Relative-to-subject information can be *"domain-dependent"* and *"domain-independent"*. Domain-dependent information shows the knowledge level and ability of the learner at the certain moment of time. Domain-independent information is not dependent on the offered content; it is for example, motivation, skills, learning style.

In educational AHS (Brusilovsky [4]) LM data is divided into two big groups: *domain-specific information* (DSI) and *domain-independent information* (DII). Domain-specific information contains student knowledge model that describes student knowledge level, insight about knowledge, learner mistakes and records about learning habits and ratings. The domain-independent information includes information about the learner skills based on his behavior. DII includes also learner learning goals, his cognitive abilities, motivation, background, experience and preferences. The work [27] also has similar data included in the user model division: *domain-independent data* (DID) and *domain-dependent data* (DDD). Domain-dependent data stores specific learner knowledge from the domain that system concludes about the learner. Domain-independent data includes two elements: the Psychological Model and the Generic Model of the Student Profile [22]. Psychological data are connected with the student exploration and emotional aspect. The Generic Model of the Student Profile keeps user interests, common knowledge and experience.

Another LM division is based on the way how data about the learner is gained: *"content-based"* or *"collaborative"*. In content-based case, data are collected or concluded about the learner only from his interaction with the system. In collaborative case, data is obtained from other similar learner groups that share, for instance, similar interests and necessities [40], and is used for a certain learner.

The user model data can be *"visible"* and *"opaque"*. Visible data can be changed by user with the help of questions-answers offered by the system. On the contrary, opaque LM data are not available for the user [19].

In [25], [26], [40] the division of data by its life-cycle in the system used in the learner model or by learner interaction with the system (values are changing or not):

- *Static data* is data that are not changed during the student and system interaction;
- *Dynamic data* is data that changes depending on the student learning progress and interaction with the system.

Static data types are personal, personality, cognitive, pedagogical and preference data [13]. Static data is collected either once at the beginning of system utilization or after a determined period. This data stays unchanged during the system utilization. Dynamic data is gained based on learner interaction with system. Dynamical data is divided into *performance* data and *student knowledge* data. *Performance data* is data gathered from the user and system interaction, and this data summarizes the

information about student's achievements during the course session and is being continuously restored. *Student knowledge data* is data that describes knowledge concepts and competences. This data set gathers information about student progress in the course of learning.

2.2. Analysis of the Data Included in the Learner Model

In this section eight works describing adaptive systems have been considered, and data included into user model have been analyzed. The research was complicated because in data categories used in these works were similar by meaning but with different names and vice versa, had similar names but category content was different. By making article research the most important data categories used in viewed scientific works were selected: personal data, pedagogical data, preference data, personality data, cognitive data, history data, device, context, interests of user, interests gathered by system, results of assesement, domain expertise, acquired knowledge, performance data, deadline extend, student knowledge currently. Below one may observe the categories and data included in them depending on the category occurrence in the viewed works.

Personal data is a category without which no system can do. It includes user biographical information gained, for instance, from the registration form. This category combines personal information, demographic information and identity data. Data included into the personal data category is similar for all authors:

- In [13] authors include in this category student name, special accessibility needs to course materials that the student must have; affiliation; student's professional activities; list of degrees and qualifications; information about student security and access credentials.
- In [10] personal data is gender; age; language; culture; name; email; password.
- In [27] personal information is name; email; password; demographic information is age.
- In [1] personal data category includes name; surname; age; language; media type; login.
- In [41] as demographic information: gender; age; native language; social-cultural parameters: formal education, family income is considered as personal data.
- In [25] authors include in personal data category personal information: name; age; address books; demographic information: date of birth; gender; nationality.

Next category that is mentioned in almost every work is *pedagogical data* that describes how and what to learn. This category includes programs, topics, course collections and course sequence. In the majority of examined scientific works this category includes also learner knowledge before adaptive system utilization, for some authors this data was described in the personal data category. Data sets included in the pedagogical category of each article author significantly differs, for instance:

- In [13] this category consist of learning style; learning approach; course objectives – concept list that each student must acquire during the course session; course evaluation; course navigation control, i.e., how the course content is navigated.
- In [27] authors include in this category academics backgrounds, for example, technological studies contrary to economically; qualifications: certificates;

background knowledge: knowledge collection that is transformed into concepts; ability to determine qualitative, quantitative and probably user acquired concepts and knowledge; background knowledge: knowledge collection translated into concepts; plan.

- In [1] student knowledge level in certain concepts of the onthology-based learner model is marked with very low, low, medium, good or excellent.
- In [3] Brusilovsky calls this data a background that contains basic knowledge with which the user started to employ the adaptive system.
- In [29] authors include skills, knowledge, abilities and plan in this category.
- In [41] the pedagogical data category includes the learning plan.

In more than a half of scientific works data that falls into the category of *preference data* is observed. This category keeps student preferences relating to the system adaption. Majority of the preferences are taken from the student, but the remaining part is defined by system administration. Characteristic examples of this category are the following:

- In [13] this category includes preferred presentation format; preferred language for content display; web-design personalization; command personalization; personal notebook; sound volume; video speed; subtitles.
- In [27] authors include in the preference data category learner defects, for instance, bad sight; domain of application user localization.
- In [1] authors include in this category specific data that is necessary for organizing learning process based on learner ontology model.
- In [3] Brusilovsky explains that the system cannot calculate this data, therefore, it is gathered directly or indirectly based on the user activities.

The next category that was distinguished is *personality data*. This category gathers data that describes student as a personality: learning style, concentration skills, collective work skills, relationship creating skills, individual features and attitude towards learning. A part of these data can be gained via tests. All in all, authors in this category have included similar data, for example:

- In [13] authors combine in this category personality type; concentration skills, where the base is average time that is used for learning; collaborative work that characterizes student skills to work in groups; relational skills that characterize student skills to communicate with teacher.
- In [27] authors include in personality data category learning style; information reception abilities – cognitive capacities; traits of personality: introvert, extravert; activity; inheritance of characteristics that classifies users, so that further system could create learner stereotype models.
- In [41] this category includes specific data – emotional state, it is ability of adaptive system to model determined user emotions with purpose to make system behavior correction.
- In [29] authors include attitude in personality data category.

For successful adaptive system utilization it is necessary to have data on user experience in work with computer, certain software and adaptive system. This data is described by the half of all authors, the data type are gathered in the category *system experience*, for instance:

- In [13] authors keep in the user model experience level that describes student's ability to work with an e-Learning system and student's experience in computer utilization.

- In [3] Brusilovsky defines experience as how familiar the user is with system and how easily he orients in it.
- In [27] this category is called aptitude.

In the half of the reviewed scientific works the category *goal* or *motivation* is presented. This is data about the system user long-term interests [25]; data that characterizes reasons why the learner does some actions (for example, searches and uses specific information) [10].

Cognitive data category describes what reference types a student has. These characteristics can be obtained by tests. This data has an important role in the system adaption ability to the learner. These data types are found only in three of eight reviewed works. For example, in [13] this category includes cognitive styles. Authors in [10] describe the data that characterizes the way of how the user processes the information.

Below are listed categories which include data used in several works only. *History data* category includes data that contains information about user activities in the system. For example in [10] information about the last user interaction with system (log file) is considered. In [27] authors use data about access of each page. In [1] authors include in history data category the data on learner navigation during resource learning process.

Device category incorporates data that characterizes user environment during the adaptive learning system utilization. In [10] it is hardware; screen size; download speed. In [27] this is data connected with the user environment, for instance, screen resolution.

Context category incorporates data which characterizes the user access place. It is relevant in cases when someone is using different devices to access the adaptive system. This data intersects a little with the device category. In [10] in this category authors keep information about the access environment, for example, access from home or from educational institution. In [41] wider information is included in this category: user location, time, physical and social environment, used devices, etc.

In the viewed papers Interests category is mentioned. For one part of authors those are interests that the user indicates himself, for the other – interests collected by the system based on the user activities. For better understanding of the observed interests, this category was divided into two parts: *Interests of user* and *Interests gathered by system*. In [10] the system collects interests from user keywords and searching results. In [27] authors examine person's interests, which are used to adapt navigation and content.

For saving learner knowledge data categories that characterize specific knowledge types are used. *Results of assessment* category contains the learner knowledge test data, for example, [27] keeps data about all tests and exercises. *Domain expertise* determines knowledge in topics that the user has interest for [10]. *Knowledge acquired* describes learner knowledge in the certain moment, for example, in [27] it is mentioned that the learner knowledge is transformed into concepts.

Summary about the examined data categories of user model is shown in Table 1. Table column names correspond to the researched articles, and rows – to data categories. Category utilization in certain article is represented with a "+".

When analyzing the results of Table 1, it is obvious that personal and pedagogical categories are the most common in the learner model. In the works of several authors there is no precise borderline between categories personal and personality and the same data is included into personal and personality categories. Cognitive data is similar to personal and personality data, where data that characterizes learner and significantly affects learning process is saved. One of the widest and most important categories of

the user model is pedagogical category, which incorporates learner basic knowledge and learning plans.

Table 1. The frequency of the learner model data category utilization in scientific works

Data category type	[29]	[3]	[25]	[41]	[13]	[10]	[27]	[1]
Personal data	+		+	+	+	+	+	+
Personality data	+			+	+		+	
Cognitive data/style					+	+	+	
Pedagogical data	+	+	+	+	+		+	+
Preference data	+	+			+		+	+
History						+	+	+
Device				+		+	+	
Context/Environment	+			+		+		
Interests of user	+			+			+	
Interests gathered by system						+	+	
Goal/Motivation		+	+	+		+		
System Experience		+			+	+	+	
Domain Expertise						+		
Results of assesment	+				+		+	
Knowledge acquired	+						+	
Deadline extend							+	

3. Learner Model Modeling

An adaptive system continuously collects data about the learner. This process is called user modeling and it is quite complicated. In this process the activities in LM, mechanisms used in modeling LM and the way in which LM saves data must be taken into account.

3.1. Formation Stages of the Learner Model

First, the adaptive system initializes the user model, and only after that data is being refreshed in the LM. Several authors highlight one more stage that involves learner data mining and concluding. Extensive research about the educational data mining is found in the review article [38].

After making article analysis, the authors of this paper concluded that the most widespread l*earning model formation stages* are the following*:*

- Initialization – information and data gathering about the user, and user profile formation that is based on obtained information. During the initialization process the structure of the user model is defined as well as reasoning methods, and memory (i.e., information about user abstraction state in a certain moment of time) in the user model. There are two ways how to obtain data: explicit questions and initial tests. This stage is used in the articles [9, 16, 25, 30].
- Updating – the system must be ensured with the learner model actualization; the system observes user activities, evaluates user achievements, learning progress dynamics and makes the reflexive link analysis from the user's

interaction with the system. All these activities are executed by the system implicitly or explicitly. This stage is covered in the articles [9, 16, 25, 30].

- Reasoning (i.e., extraction of the new information about the user from the existing available data) [13]. Data mining utilization to ensure adaptation is a new research direction which is reviewed in [21, 38].

3.2. LM Construction Techniques

The user modeling technique describes how the user model is created and maintained. There are many techniques for modeling the user model and supplementing data in it. For example, there are such LM construction techniques as: a stereotype model, an overlay model, a combination model, a perturbation model, a plan model. The oldest and the most frequently used ones are a stereotype model, an overlay model and a combination model [6].

A Stereotype model is often used for LM to define some default values. In case of the learning system, users are divided in the system-offered categories, i.e., stereotypes. It has been introduced by Elaine Rich. A stereotype is a simple collection of the aspect–values that describes the system user groups [36]. The benefit of it is that with a small amount of information it is possible to conclude a lot of new assumptions about the user. The stereotype review and utilization examples are given in articles [3, 6, 7, 12, 15, 20, 30, 37].

An Overlay model is widely used in adaptive hypermedia systems. A student knowledge model is being constructed based on the concepts. A user model is restored based on the user progress in the system. This model allows creating knowledge about a student in each topic in a flexible way. The modeling approach of the overlay model is based on the domain model, which is often constructed with the help of the knowledge network or the knowledge hierarchy tree. This method requires dividing domain model in different topics and concepts [3]. Nowadays domain model can be built with the help of ontology [30]. The overlay model review and utilization examples are provided in articles [6, 7, 15, 27, 30].

A Combination model employs both of the previously mentioned models. First of all, students are divided by stereotype, and then this model is gradually modified into an overlay model. This model is used for educational AHS [6].

A Differential model is described in [30]. It is another version of overlay model, where the knowledge that a student must acquire in a certain period of time is represented (i. e., expected knowledge). This knowledge can be considered as the knowledge that is missing.

A Perturbation model. Some models are not interested in learner mistakes caused by wrong perception or lack of knowledge. This model represents learner knowledge as an overlay model plus his mal-knowledge [30].

A Plan model incorporates successive student actions for achieving certain goals and desires [30].

3.3. User Data Modeling Methods

Static data elements are modeled with *Attribute-Value Pairs* [25]. Attributes are terms, concepts, variables and facts that are important for both the system and the user. Their values can be of the following types: boolean, real or string. For modeling uncertain information elements like user knowledge more difficult approaches there are used

such as rules with certainty factors, fuzzy logic, Bayer probability networks or Dempster-Shafer theory of evidence [16]. User condition-based language modeling approach is applied to the *dynamical data* elements, where a connection between the provided service and a context is based on if-then logic.

To represent the relationship between data elements the hierarchy tree modeling approach and ontology are used. The user ontology is described in following articles: [1, 13, 29]. In [43] a research about e-learning platform knowledge management with the help of ontology is described. Systems used for user modeling are:

- UMT [2] that allows developers to define hierarchically arranged user stereotypes, rules of the user model conclusions and contradictions.
- PROTUM [44] represents the user model content as a list of constants, where each constant is attached to a certain type and confidence factor. This tool has deeper stereotype retraction mechanisms than UMT.
- TAGUS [32] represents assumptions about the user with first-order formulas by indicating different types of assumptions. This tool allows defining stereotype hierarchies and contains conclusion mechanisms.
- UM [17, 18, 19] toolkit3 includes user modeling by indicating user knowledge, views, desires and other user characteristics with attribute-value pairs.
- BGM-MS [19] user or user group stereotype choice is based on the assumptions that are gained using predicate logic. User knowledge defining is based on conclusions that are obtained employing different assumptions.
- DOPPELGÄGER [31] is a server that collects information about the user with hardware and sensor software. A user can visualize, check and edit his data.

4. Conclusions

Adaptive system range is wide and there are a lot of researches in this scope including the user model utilization.

During the analysis of the adaptive system structure authors concluded the following: (1) depending on the type of the adaptive system, model names included in it may differ but their essence and tasks remain similar; (2) each adaptive learning system must have at least three components: (a) a domain model for keeping system-offered knowledge; (b) a learner model (user model, student model) which describes in an understandable way for the system a person sitting in front of the computer and willing to learn; (c) an adaptive model (interaction model) with the help of which system-offered knowledge is delivered to the learner in an understandable way.

One of the most important adaptive learning system components is the learner model. It includes data from the user profile, however, when making a good adaptive system learner model can also include additional data characterizes the learner in a more comprehensive way.

It would be recommended to divide all data included in the learner model into some basic categories:

- Personal data, where data about the personality identity is stored (name, surname, login, password, language, gender, date of birth).
- Personality data – data that characterizes the learner as personality (individual features, learning style, concentration skills, personality type, collective work skills, emotional situation, attitudes).

- Pedagogical data – data which characterizes anything that a learner must learn (programs, themes, course sequence, plan).
- Preference data – data that adapts working environment for learning (language, presentation format, sound value, video speed, web design personalization).
- System experience – data that characterizes learner's earlier gained experience with computers and software used in the learning process (obtained certificates, skills in e-Learning system utilization).
- Cognitive data – data that represents reference types of the learner.
- History data – data about all learner's activities.
- Device data – data that characterizes working environment of the system user (hardware, download speed, screen resolution); learner's location, time; and devices used.
- Student knowledge at the current moment of time – data that describes student knowledge gained in the learning process.

Future work would be some kind of practical realization of the learner model using obtained results about data included in the learner model and their types.

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