# Adaptive Learning Analysis

Velimir Graorkoski, Marjan Gusev[1]

[1] Institute of Informatics, University of "St. Kiril and Metodij", Skopje, Macedonia,
marjan@ii.edu

**Summary.** In this paper, new theoretical views of the adaptive learning, conclusions from several scientific researches in that area, as well as a proposed direction for implementation of some of its parts as a practically used entity at II, are presented

**Key Terms:** Learning, e-learning, adaptive learning, learning environment, real-time learning, intelligent systems, learning efficiency, adaptive learning environment - ALE, concept, learning element/object, knowledge, learning mechanism, instance, instantiation, learning efficiency time, adaptive learning system, distance learning, artificial intelligent systems, maximum learning efficiency, adapted learning environment, knowledge degree, perfect adaptive learning environment

## 1 Introduction

In the nature, there are systems that always have some kind of response when they enter an unknown environment or state. Those intelligent systems [9] gain reactions according to the environment that encircles them, by learning [8]. Learning [8], as a process (still not entirely explained) that increases the amount of reactions (information or skills), does not only represent simple accumulation of data from the environment, but within itself includes complex classification types and distribution (probability in first order). Precisely, that complexity of the learning [8] leaves space for differences among the intelligent systems [9] by means of how they receive information from the environment. Two intelligent systems [9] in same learning environment (we define it as set of elements involved in the process of learning [8]), do not have the same learning efficiency [2] (defined as division between knowledge [11] and the sum of all the received information, with proportional dependence between the efficiency [2] and knowledge [11] – Figure 1), i.e. one of them shows larger efficiency [2]. And in those cases it is usually hard to make changes in the second intelligent system [9], so that it can reach the efficiency in the learning [2] of the first one. We will take the learning efficiency [2] in the interval between 0 and 1 (according to the theory of probability), so the maximal efficiency of the intelligent system will aim

towards 1 (100% from the whole amount of received information are transformed into knowledge [11]).

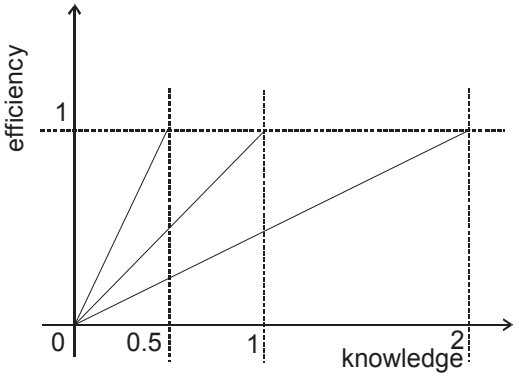


**Figure 1.** Dependence of the learning efficiency from the knowledge for different amounts of received information (0.5, 1 *и* 2 appropriately)

We consider the possibility the learning environment to adapt to the learning mechanism of the second intelligent system [9]. We were given the support by the behavior of the intelligent system [9] in different learning environments. The learning environment itself influences the efficiency [2] of its learning mechanism (by this term we refer to as set of functions defined on the set of concepts [3]), while the dependence – Figure 2 is not linear because of the lack of precise gradation of the different learning environments according to their capacities of emitting learning objects [10, 14]. The problem, towards whose solution we will strive, is how to choose the most adequate environment in which it will learn most efficiently, which is approximately equivalent to how efficient to adopt (with array of changes) the existing environment in which it is situated, to its learning mechanism.

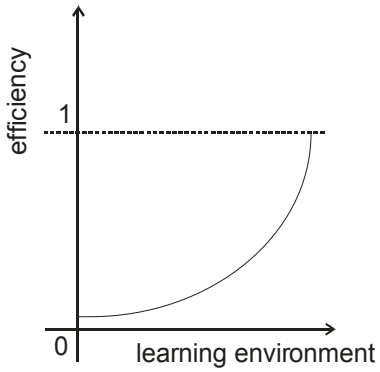

**Figure 2.** Dependence of the learning efficiency from the learning environment (without defined measure)

When it is spoken about an intelligent system [9], in first order we will think of the human, although in the nature he is not the only system that shows intelligent behavior. But he is the only (for now) known system which tries to jump over the difficulties of finding the simplest way of improving the learning efficiency [2] of one intelligent system [9], examining himself together with the surroundings. With that kind of approach of adapting the learning environment to the human, arisen a lot of ways and methods of learning [8] like e-learning [5] or real-time learning [6]. We will strive to gain an idea that promises great success – construction of intelligent system [9] or adaptation of an existing one, who will apply the best methods for increasing the learning efficiency [2], or create new even better procedures to achieve that increase.

If e-learning [5] is a result of the attempt the electronic devices to play role of learning environments (with that the unit that learns will be given the ability to remove the unnecessary defocusing from costs, interrupts, …), then the real-time approach achieves increase of the learning efficiency [2] instantaneously after the receiving of the information [6], so the learning environment (for example, the teacher, the trainer, …), according to its capacities, observes the learning mechanisms of a small subset of the set of intelligent systems [9] affected by that environment, one by one. But, there exists a better approach that can be achieved with changes and improvement of the previous two, and that is the adaptive learning [7], in which the role of learning environment will be given to an intelligent system [9] (we will force artificial), which most successfully will fit to the learning mechanism of every element from the set of intelligent systems [9] that learns, treating it by itself, and also keeping the possibility of serving several intelligent systems [9] in same time. When we mention the term adaptive learning [7], we will think of a wider theoretical notion [1], rather than of its implementation of e-learning [5] (as adaptive e-learning).

## 2 Motivation

The theory of adaptive learning [7], as well as the used terminology are still not enough standardized, although they are more than one decade present in the science. The reason for that in large part is the existence of different implementations of the adaptive learning environments (by adaptive learning environment in this analysis we will refer to as learning environment in which the learning efficiency [2] of one intelligent system [9] is changing independently from the gained information) – Figure 3, where different approaches from the constructors and research teams exist, which by the way defined and shaped the notions and terms according to the achieved results [3, 4]. We assume that till certain degree it is understandable because of the disjunctive research techniques, and although there are some attempts for complete standardization, still because of the theoretical reviews of the practical implementations of the adaptive learning [7] (without difference whether it is e-learning [5] or not) our opinion is that it will not happen in near future.

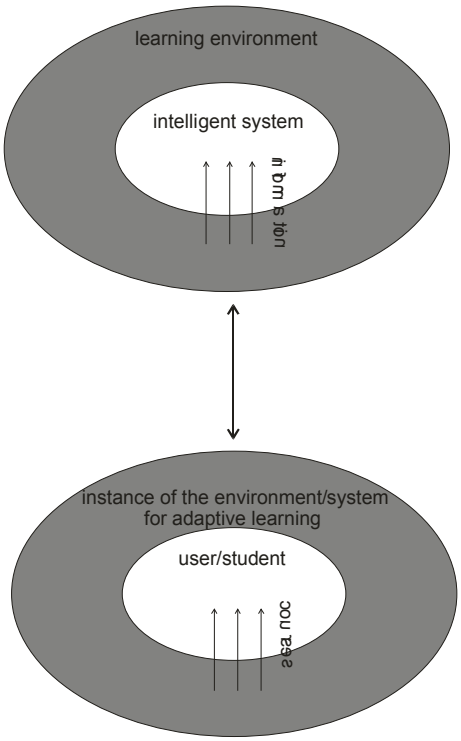


**Figure 3.** Equivalency between theoretical placement and proposed implementation of higher level

On Institute of Informatics, systems for distance learning [13], as well as testing, function for several years. However they can not entirely replace the teachers from the process of learning [8]. Also it can not be expected from the teachers to adapt to the learning mechanism of every student or at least smaller group of students – Figure 4. For better explanation of the possible solution of this problem we introduce new term – adapted learning environment (learning environment in which limited number of intelligent systems [9] have approximately equal maximal learning efficiency), as well as new meanings of the terms – instance (the adapted learning environment derived from the adaptive learning environment) and instantiation (deriving of adapted learning environments from adaptive learning environment, for groups of users or single users – Figure 4 in which they can achieve greater efficiency of their learning). If a transformation is executed on the existing systems into adaptive learning environment or constructed new, after it is appointed the best possible adaptation level (we define it as instance of the adaptive learning environment in which the intelligent system [9] shows certain learning efficiency [2]), and also the possibility for its implementation, then it can be considered a bigger replacement of the teachers in the learning process with instances of adaptive learning environment. Furthermore if it is appointed that the highest possible adaptive level is achieved, then during the theoretical review (that will be done in parallel), a new terminology will be introduced or a correction to the

existing used terms will be made, which will be excellent proposal for supplementing the existing standards. Of course, that will depend on the achieved success of the implementation of the used adaptive methods.

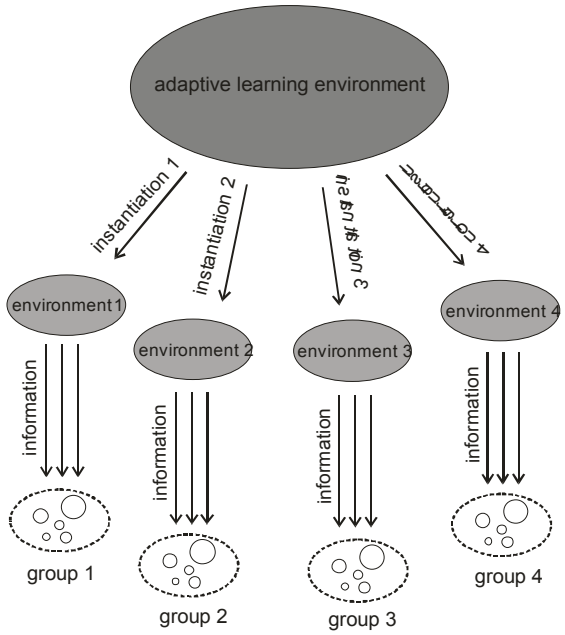


**Figure 4.** View of adaptation towards smaller groups of users

As a small explanation of the so far used terminology, the warning that the terms "adaptive learning environment" and "environment for adaptive learning", although grammatically different, they are both referring to ALE, can serve well. The same thing happens with the following one that the terms "adaptive learning environment" and "adapted learning environment" are different, although they seem as they refer to one thing. The second one refers to only one instance of ALE.

The main goal that we will strive to, will be a realization of adaptive learning environment, which will aim towards perfect adaptive learning environment (adaptive learning environment whose instances are totally familiar with the learning mechanism of the intelligent systems [9]).

## 3 Overview of Some Scientific Researches with Implementation Proposals

Frequent example of developing an adaptive learning environment is the development according to categories of adaptation, which can often mutually overlap. Usually those categories (proposed at Johannes Kepler University in Austria, based on foregoing established models and processes) are [3]: adaptive interaction, adaptive course deliv-

ery, content discovery and assembly, and adaptive collaboration support. In each of these categories, some features of the adaptive learning [7] are integrated, especially in its implementation in e-learning [5].

Adaptive interaction [3] represents an adapting to the system's interface with which the user interacts with the system, without changing the way of learning [8]. Adaptations at this level include: the employment of alternative graphical or color schemes, font size, as well as every other scheme that can respond to the user's needs, according to its capabilities when it comes to the physical communication with the system.

Unlike the first category, the adaptive course delivery [3] consists of adaptive techniques on which the nature itself of the adaptive learning environments used in e-learning [5] depends. More specifically, it represents an adjustment of the course's contents to the characteristics and needs of the user, so that optimal learning [8] and minimum effective time spent in interaction can be achieved. Examples for this category are (re)structuring of the dynamic courses, adaptive navigation through the course's contents, and adaptive selection of course's fragments.

The content discovery and assembly [3] is a category in which with adaptive techniques the learning materials (contents) are isolated and organized from potential set of sources. The isolation and organization are made according to the conclusions derived from the monitoring of the users' characteristics. Usually every user strives to isolate the learning material from known sources which are close to his learning mechanism, as not in case of the teacher (which usually has wider range of known sources of information, but often does not include those close to the user), but in that process he can not discover those unknown ones which are also closed to him.

The last category includes adaptive techniques that would appoint the common communication among different users, isolate the common tasks, and make a direction towards accomplishing the different goals [3]. In that way, an encirclement of the user's isolation to other users from the other instances of the adaptive learning environment simulated from the system of adaptive learning [12] will be made. Also the possible similarities will be appointed with the other learning environments and their users, so that they can become potential objects for successful interaction.

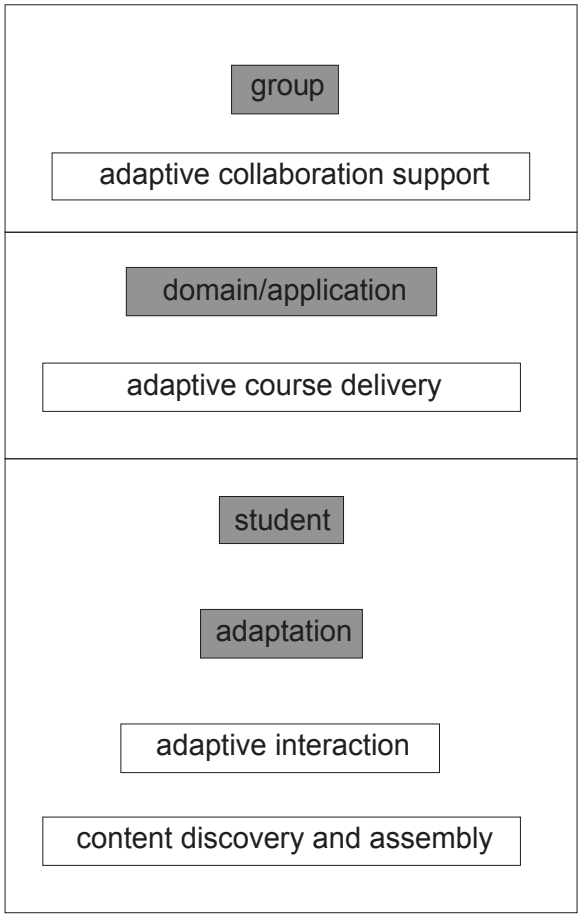


**Figure 5.** Categories of adaptation based on models

These categories of adaptation are based on well chosen set of models – Fifure 5: domain (application), student, group, adaptation. Very interesting and also important is the definition about the relationship between the term learning element/object [10, 14] and the term concept [3] for the first model used in the adaptive system for e-learning [5] AHA! [3]: if learning element [10, 14] Y is read, then it provides knowledge [11] for the concept [3] D. For the same model, a granularity is shown together with definition for learning elements – atoms, as a consequence of the following example. Let there be two descriptions for a single concept [3], the first one short, and the second one detailed. Then some learning elements [10, 14] from the second description are sub-elements of some learning elements [10, 14] from the first description. In case of non-existence of more detailed concept description than the given one, then the learning elements [10, 14] from that description are called atomic. In the AHA! system that kind of granularity is represented with division of the page to paragraphs and sub-paragraphs.

Peter Brusilovsky, from his point of view represents AIES (adaptive and intelligent educational systems) [4]. This type of systems is shown as a successor of ITS (intelligent tutoring systems) and adaptive hypermedia systems, at the same time merging their strategies of delivery of the learning materials.

ITS [4] are based on three crucial technologies like: curriculum sequencing, intelligent analysis of student solutions, and interactive support for problem solving (including an example-based support). Each of these technologies contains small fragments of adaptation. Thus, the curriculum sequencing appoints the best possible order of the learning tasks (a permutation of: examples, question, problems, …), so that the student could find its optimal path for gaining knowledge [11] for the learning goal (defined as subset of the set of concepts [3] of the all learning materials [8]). The intelligent analysis of student solutions guides the so called intelligent analyzer, which locates the eventually existing mistakes and if possible, delivers the correct parts or gives better proposals for the solutions. Step forward is made at the interactive support for problem solving, where the student solves the problems step by step, by getting feedback from the system for every made step, i.e. the system does not have to wait only for the final solution made by the student. Further more, with the example-based support, the student is given the ability to gain proposals for development of the solution in the steps themselves, rather than to wait for correction to his incorrect approaches.

Adaptive hypermedia systems [4] most often use adaptive navigation technology in hyper-space, to help during the student's orientation in the learning materials, at the same time forcing the world web as primary medium. Those systems have to be aware of the goal knowledge [11] towards which the student strides, as well as some previously appointed data for his knowledge degree (measure that can be defined according to the implementation, in this case it is similar to a knowledge grade) in the field that covers that goal knowledge [11]. It is important for the system to find better page if possible, from the hyper-space, and according to her, to be able to discover others even better than the previous by generating access links between them if they are not already present. The student, even without the guidance of the system, may still succeed in finding the goal hypertext page using his own search logic, but the point is to enable him to make his searching more efficient with improving the speed to achieve the goal, and to gain new knowledge which will back up the concepts [3] of the goal page's contents. The adaptive hypermedia systems also use technology for adaptive presentation with which help, the contents and the face of the goal page are adapted according to the student's characteristics.

One such realization, motivated from the Brusilovsky's work is NetCoach [15], where the curriculum sequencing [4] and adaptive navigation [4] come to the fore. The idea as a result of which NetCoach is developed [15], is constructing of system which will help in the creation of adaptive courses. In the system itself, several different adaptive elements are distinguished which can play a role of models: knowledge base, user, curriculum sequencing and link annotation, and learning goals. Precisely the knowledge base consists of concepts, but here they are defined in another way as internal representations of the pages that will be displayed to the student. User's model is organized so that any possible information needed for the student is stored, and later from them conclusions can be derived for his characteristics (capabilities) during the learning. The third model enables the face of the page to be according to

the student's characteristics including the permission to navigate from one set of contents to another with the help of the links. The most important model for those students who do not have attention to complete the knowledge for a given course, is the learning goal model, which automatically calculates (according to his knowledge [11]) that a single user should not be allowed to continue the course because by choosing some pages to be jumped he achieved his goal during the learning.

A little different approach uses the team of Richard R. Johnson, which while the solution of the problem of the training systems [7], from the theory of the adaptive learning, manages to implement in its modules the following categories: learning content, pre-test questions, and post-test questions. Interesting is the fact that in the last two categories for questions, a certain weight is assigned to every question, so that a privilege can be given to the most important achieved knowledge [11] from the user, during the verification of his achieved success in the training process.

## 4 Conclusion and Comments

The notion adaptive learning [7] in most cases is still used in close relationship with the e-learning [5], although that is only one of the possible implementations. The reason for this is the lack of clear theoretical representation or lack of standardization, especially when it comes to examining the learning environment, capabilities and conditions under which the adaptation will be made, and also to the adaptation process itself, which the authors of the references used in this paper, are admitting. Thus, for example, the defined relationship between the learning elements [10, 14] and the concepts [3] at the domain model for the AHA! system could be generalized – Figure 6: if one learning element [10, 14] is accepted from the learning mechanism of a single intelligent system [9], then the intelligent system [9] gains knowledge [11] for a single concept [3]. According to this definition, the notion knowledge [11] can be reformulated – set of learning elements [10, 14] and concepts [3]. Also at the adaptive course delivery [3], the term for minimal effective time spent in interaction, can be reformulated into new term – efficient learning time, which could be defined as time needed for the intelligent system [9] to gain certain knowledge when it is situated in adapted learning environment. The efficient learning time defined like this can serve in the researches that follow during the appointing the differences between learning mechanisms of two or more intelligent systems [9] in same adapted learning environment (for example, in order to gain the same knowledge, another intelligent system [9] will need more or less time).

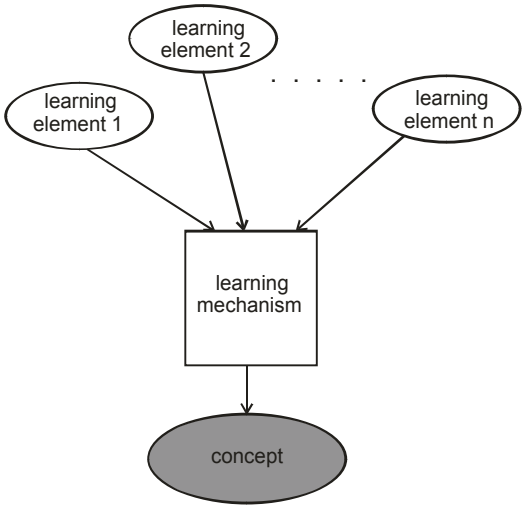


**Figure 6.** Relationship between learning element and concept

Certain good side is the fact that in both researches from the Johannes Kepler University and Brusilovsky's, there are some related points in the approach of modulation of the implementations. More massive categories without précised models are used by Richard R. Johnson. But in the contents of Brusilovsky's work, there is unnecessary classification of the adaptive navigation, at the adaptive hypermedia systems, and the curriculum sequencing at ITS. Actually the adaptive navigation at the adaptive hypermedia systems is a special case of the curriculum sequencing at ITS, but used on learning materials in the shape of hypertext. The biggest weakness at the categorization and models of the first approach is its internment to possible intelligent automodification (the system to be able to introduce new models and categories, when it calculates that the existing ones can not increase the learning efficiency [2] of the student anymore, but are aware that it is yet possible to do it), while at the so called intelligent parts of Brusilovsky's proposed implementation, the biggest disadvantage may be the overwhelming derivation of previously known student's data, instead of using more of those characteristics gained during the process of learning [8] itself. The third approach [7] with its non-précising of the models leaves a space for more free manipulation with them and their treatment as separate learning environments, and at the same time their categories will be given a role of models. Also the weight that is assigned to the questions may be used as a feedback towards the adaptive learning environment for the characteristics of the intelligent system [9]. But the problem at Richard R. Johnson's work appears in the crutching to the definition of adaptive learning [7] from the beginning. The weakness of that definition lays in the part when it says that the adaptive learning system adapts according to the needs of an individual user, or generalized: adaptive learning environment adapts itself according to the needs of the intelligent system [9]. We will add that the adaptation besides according to the needs of the intelligent system [9] also will be made according to the needs of its learning mechanism (of which the intelligent system [9] is not aware, and therefore cannot be treated as his need).

The most general conclusion that can be derived from the past researches and results in the field of adaptive learning [7] is that the common goal of every team – creation of adaptive learning system [12], is reduced to creation of the system that will simulate adaptive learning environment in which the intelligent system [9] will achieve maximal efficiency (in this part we can give a definition for this term- learning efficiency [2] for an intelligent system [9] for which does not exist another adapted learning environment in which its learning mechanism shows increased efficiency [2]) during the learning. If it comes to artificial intelligent system, then it is relatively easy to get its instance of the adaptive learning environment, assuming that some of the basis from which it is constructed, are known. For now on, that is not a case with the rest of the intelligent systems [9] (those that are non-artificial), like the human, because of the still present secrets of the way his learning mechanism functions, although it is known that it varies for different units. Very important part of the conclusion is the non-constant state of the learning mechanism of a single intelligent system [9], i.e. the influence of the recently gained concepts [3] of knowledge [11]. Thus, if the adaptive learning environment instantiates an environment in which the intelligent system [9] shows, until that period, the best learning efficiency[2], that environment should not be forced too long because the acquired concepts [3] triggered changes in the learning mechanism of the intelligent system [9], which may show better efficiency [2] in other instance. Concrete example for that can be a student for who the professor thinks that he can learn some mathematical field only with showing him already solved examples of mathematical problems, but in meantime, as the number of examples received by his learning mechanism increases, so he becomes aware that he could gain knowledge [11] even more effectively if he gains knowledge about several theoretical concepts which are common for every solution of the problems. That is another pointer that even the adaptive learning environment itself should "behave" intelligently.

As if for the concrete usage of these defined concepts of the adaptive learning [7] in the II systems, part from the referenced experiences, but the goal will be to stay close to the proposed theoretical rules or those new rules with which the theoretical part would be enlarged, and will be introduced during the researches and the realization. In this decision we are impelled by the incapability of the NetCoach [15] system to produce adaptive courses by itself, and to accomplish that the intervention from an intelligent system [9] – the administrator or the user is needed, which clearly shows that the system does not plat a role of an adaptive learning environment and does not produce adapted courses, but adaptive, which again can not replace the adaptive learning environment itself because of the limited amount of materials. Therefore in first order, we will count that the most valued usage will be the one with weighted automata in the implementation itself of the part that will represent the adaptive learning environment. And because in the role of intelligent system will be the student, whose learning mechanism during the initialization is totally unknown, different statistical and probability rules and methods will be applied on the feedback information, gained from his past approach to the learning materials and the results from the previously made tests.

## References


1. Margaret Martinez – "Adaptive learning", at The Training Place, Inc. (2005), 1
2. John V. Moran – "ROI for e-learning", at American Society for Training and Development (2002), 1
3. Alexandros Paramythis, Susanne Loidl-Reisinger – "Adaptive learning environments and e-learning standards", at Electronic Journal on e-Learning Volume 2 Issue 1 (2004), 181-187
4. Peter Brusilovsky - "Adaptive and intelligent technologies for web-based education", at Carnegie Technology Education and Human-Computer Interaction Institute Carnegie Mellon University Pittsburgh, 1-7
5. Som Naidu - "E-learning-a guidebook of principles, procedures and practices", at Commonwealth of Learning Commonwealth Educational Media Centre for Asia (2006), 1-9
6. Tom Bentley – "Incubating real time learning", at AERA SYMPOSIUM (2003), 1-7
7. Richard R. Johnson, James J. Oukrop – "Adaptive learning: technology that personalizes and expands the training experience", at Comprehensive Loss Management Inc. Minneapolis, 1-5
8. Jorg Denzinger – "Multi-agent systems", 1
9. J. L. Castro - "Presentation of the seminar on new trends on intelligent systems and soft computing", at Granada (2003), 5
10. Maja Stracenski, Goran Hudec, Ivana Salopek - "Designing e-learning materials with learning objects", at CARNET USERS CONFERENCE - CUC (2004), 3-4
11. Katerina Zdravkova – "Programming systems", at Institute of Informatics Skopje (1994), 9-13
12. Ian G. Kennedy, Sanaz Fallahkhair - "Simple web-based adaptive learning technology", at IEEE Workshop at the International Summer School on Educational Technology, 1-5
13. Susan Imel - "Distance learning", at Center on Education and Training for Employement College of Education Ohio State University (1998), 1
14. Jacques du Plessis - "Learning objects using language structures to understand the transition from affordance systems to intelligent systems", at Interdisciplinary Journal of Knowledge and Learning Objects Volume 1 (2005), 1-2
15. Gerhard Webber, Hans-Christian Kuhl - "Developing adaptive internet based courses with the authoring system NetCoach", at Pedagogical University Freiburg, 1-5