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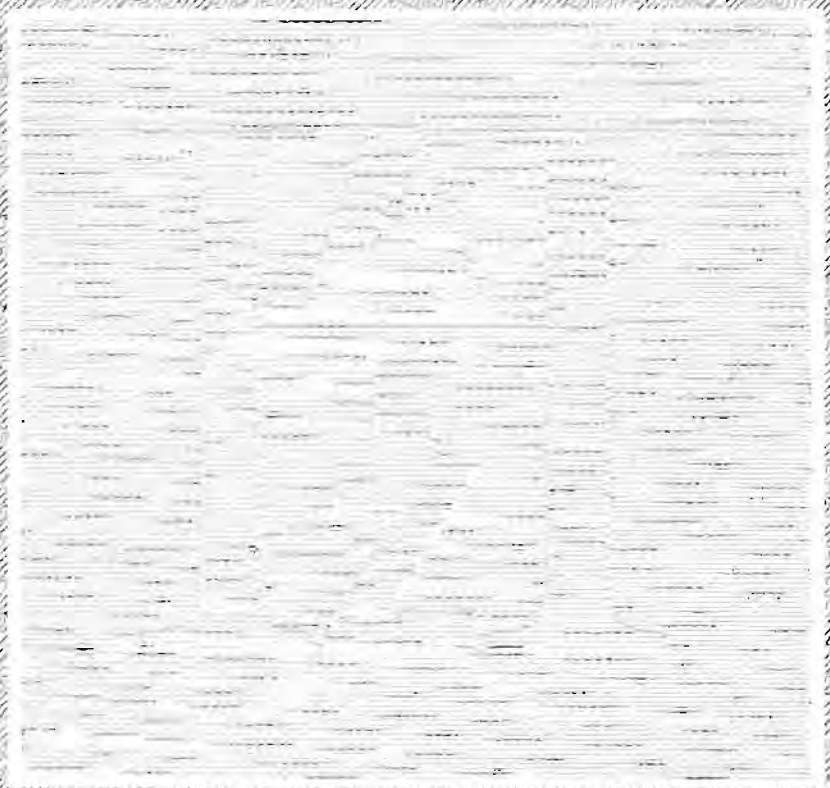

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also directors of the state institutions, members of the Croatian Academy of Sciences and Arts, deans of the faculties, rectors of the universities, experts of the UN and the EU, members of the international bodies, laureates of domestic and international awards for scientific and professional achievements... and it would take too much time and space to mention all duties and functions that our members are or were engaged in.

Beside this, we are particularly proud that we have been welcomed as a Member Academy to the International Council of Academies of Engineering and Technological Sciences (CAETS) at the Beijing Meeting 2000, and that, starting from January 1, 2005, we are to become an Associate Member Academy of the European Council of Applied Sciences and Engineering (Euro-CASE).

We are particularly grateful to our Supporting Members for providing their financial support that helps us realize our annual programs, but also for their awareness that among the HATZ members they can find internationally recognized experts to solve any problem related to the production, monitoring or technology and *know-how* transfer. In the future we shall make further efforts to realize the closer relations with the supporting members, but also to promote their participation in all contacts that our Academy is engaged in abroad. Serving the Academy, we are serving the better future of Croatia.

Zlatko Kniewald
President of the Croatian Academy of Engineering

Contents

E-Learning Paradigm & Intelligent Tutoring Systems

Slavomir Stankov[1], Ani Grubišić, Branko Žitko
Faculty of Natural Sciences and Mathematics and Education, University of Split
Teslina 12, 21000 Split, Croatia

Abstract

WWW service has enabled development of thousands of systems that are considered to be direct application of modern information and communication technology, and they have their work on a static presentation of a subject matter. Educational system capabilities incensement is gained by adding interactive, adaptive and intelligent functions and those features enable development of Web oriented intelligent authoring shells. E-learning, new paradigm enabled by electronic technology, seems like universal replacement for all researches and development that have been conducted in the last fifty years, in a field of computer systems' applications in education. E-learning is closely related to intelligent tutoring systems. Influence of intelligent tutoring systems on learning and teaching process is again actual because researchers have seen importance and relation between these systems' pedagogical paradigm and Bloom's "2-sigma" problem. Bloom's "2-sigma" problem is related to the efficacy in a knowledge acquisition while comparing individual and team learning. We present some research findings and we indicate their relationship with our own research that has been conduced over ten years. Also, we present our future work related to Tutor-Expert System model, an authoring shell for intelligent tutoring systems development in freely chosen domain knowledge.

Key words: World Wide Web, E-learning, Intelligent Tutoring Systems, Learning Management Systems, Standards in e-learning systems, Shareable Content Object Reference Model, The Two-Sigma Problem

1. Introduction

Information and communication technologies (Budin et al, 2001) have become integral part of educational systems as a support for teachers in realization of traditional education as well as replacement of traditional education with one of many new methods for realization of learning and teaching process. Information and communication technology combined with multimedia, networking and software

[1] E-mail: slavomir.stankov@gmail.com

gineering have enabled development of new learning and teaching computer systems. Last great milestone in educational technology was made by introducing Internet and WWW service, and it anticipated all educational systems to be reengineered. Computer networks technology, i.e. Intranet, Internet, WWW and specially hypermedia, have all influenced on founding so-called advanced learning technology (ALT, 2004). Those advanced technologies should be observed in a context of technological diversities from computer systems for presenting subject matter to books and textbooks that support traditional learning paradigm. New learning paradigm is learner - central. Learner is "placed" in centre of the learning environment with regard to the time as well as the place and way of learning (Wasson, 1997) and everything is embraced by single phrase – learning resources (people, knowledge, technology, medium, organization, ...). In this paper we discuss e-learning because we believe that this is new learning paradigm based on electronic technology seems as universal replacement for all researches and development that have been conducted in the last fifty years, in a field of computer systems applications in education. Besides, as stated in title, we bind e-learning paradigm with on-site and Web intelligent tutoring systems (ITS) that enable individualized approach to learning and teaching. It is known that WWW service has enabled development of thousands systems that are considered to be direct application of the modern information and communication technology. Most of these systems have very limited learning and teaching capabilities because they base their work on static presentation of subject matter. Educational systems capabilities incensement is gained by adding interactive, adaptive and intelligent functions. Those functions can be implemented by using some techniques of dynamic generation of Web content which depend on students' answers to asked questions. Usage of those technologies enables development of Web oriented authoring shells for constructing Web based ITS. The individualized learning and teaching approach is now enriched with e-learning paradigm and, what is more, it makes fundaments of our research. E-learning accents two significant determinants: (i) *Learning Management Systems (LMS)* and (ii) *standards based on SCORM model* (Sharable Content Object Reference Model) (SCORM, 2003). E-learning paradigm as well as previously mentioned determinants will be analyzed in this paper and will be related to ITS. Intelligent tutoring systems are generation of computer systems aimed for the support and improvement of learning and teaching process in certain domain knowledge, respecting individuality of the learner as in traditional "one-to-one" tutoring. Nowadays, when information and communication technologies and Internet have become inevitable, ITS emerge again because researchers have seen importance and association between those systems' pedagogical paradigm and Bloom's "2-sigma" problem (Bloom, 1984) related to the efficacy in knowledge acquisition through comparison of individual and team learning. Far from any doubt, ITS show the best results in evaluating students' achievement when being compared to existing technological learning and teaching process support, both traditional and individual (Fletcher, 2003). Thereby, we imply on connectivity of e-learning paradigm with our own ten year research related to development and implementation of *Tutor-Expert System*, TEx-Sys (Stankov, 1997) an intelligent hypermedial authoring shell for generating ITS in freely chosen domain knowledge. The TEx-Sys authoring shell was initially developed and implemented as an on-site system, and afterwards followed research, development and finally implementation of TEx-Sys's distributed version *Distributed Tutor-Expert System*, DTEx-Sys (Rosić, 2000). The TEx-Sys and the DTEx-Sys have been used on some of our university classes in the last few academic years (Stankov et al, 2002), (Stankov et al, 2003). We have created our own learning and teaching model by using knowledge bases developed by TEx-Sys. Achieved results have been used for further research that relies on Bloom's experiment (Stankov, 2002) with a view of developing our own research methodology. However, we have been working on implementing a prototype of extended version of the TEx-Sys, *extended Tutor-Expert System*, xTEx-Sys (Stankov, 2003), within a technology project founded by Ministry of Science and Technology of the Republic of Croatia. This paper presents achieved results concerning research and implementation, briefly describes e-learning environment, learning management systems, standardization of learning technology, e-learning systems' pedagogical paradigm and overview of the xTEx-Sys architecture.

1. E-learning and its environment

Improvements in Internet access availability and speed as well as computational power of personal computers, have dramatically increased possibilities for interoperability and usage of other distributed learning technologies. Consequently, different companies and associations have been developing different products for distributed learning. New products are continuously being developed and combined with existing products that define new functionalities. That became challenge for the development of the new e-learning environment. Emerson of new e-learning paradigm does not imply that existing software applications as well as traditional educational methods should be forgotten. On contrary, existing student administration, human resources and library management represent critical components in e-learning environment. Real challenge is to integrate all those components in e-learning system and its services. E-learning presents intersection between world of information and communication technology and world of education. This fact is valuable particularly when it is being used as a part of well planed and organized learning environment, but nevertheless e-learning is not a "magic ball" that will replace existing pedagogical theories, principles and standards. American Society for Trainers and Development (ASTD - *www.astd.org*) defines e-learning as a subject matter or a learning experience delivered or enabled by the electronic technology (ASTD, 2001). Formally, e-learning includes numerous learning strategies and learning supported technologies such as CD-ROM, computer based instruction, videoconference, subject matter delivered by satellites and networks for virtual education. In other words, it does not include only Web based education or distance education, but it includes different approaches in order to individualize information interchange and knowledge acquisition of participants. In principle, e-learning is based on the electronic technology, designed for enabling knowledge and skill acquisition, not only for students in formal learning and teaching process, but also for all participants engaged in long life learning and teaching process (learning while working, qualification for new vocations and new [illegible] and techniques, etc.). While consider

... e-learning environment, Khan assumes that e-learning should be able to answer the question: "What should be done to accomplish successful e-learning for different categories of students?" and he suggests multidimensional space made of pedagogy, technology, user interface, assessment, management, on-line support, ethics and institution (Khan, 2001).

In conclusion of this paragraph, we are going to mention few more relevant features of e-learning paradigm. One of them is related to dynamic growth of commercial ... (*www.brandon-hall.com*). It has performed an explosion from barely existing in 1996, to about ONE billion dollars in 1999, and foreseen about 10 to 12 billions dollars in 2003, to more than 200 billions dollars in 2010. Last two features imply that learning and teaching process benefits from e-learning and globally relates formal education (at all levels) and long-life education to the two new determinants (eoDynamic, 2001) that can be summarized in: (i) development of integrated systems for learning management, and (ii) development and promotion of standards for reusable content objects for e-learning or learning objects.

Following paragraphs present e-learning systems configuration and architecture that relies on standards for developing e-learning systems. However, it should be emphasized that introducing standards in e-learning systems will probably "neaten" e-learning area and ease the work for newcomers.

... E-learning systems configuration

We describe some actual e-learning systems configuration classes because this area is very dynamic and it is very hard to foresee what will happen in the future. ..., according to numerous literature references that represent actual e-learning systems configuration, our analysis focus is placed on *learning management systems* and *learning content management systems*. These systems have one thing in common: they are both Web based systems for supporting learning and teaching process during student's knowledge and skill acquisition

Learning Management System (LMS) presents software that globally enables total learning and teaching process administration. LMS enables student's registration, courses sequencing in courses catalogue, describing student's data and reporting everything that has been done. Besides, LMS is usually designed in the way that it can manage courses delivered by different publishers and service providers. Usually LMS configuration does not include authoring tools for creating subject matter. LMS vendors offer some additional tools for creating subject matter. Reusability goes to the whole course (one course can be delivered to many students whose accomplishments can be tracked down).

Learning Content Management Systems (LCMS) enable creating, storing, using ... reusing subject matter. Subject matter consists of knowledge grains that are called learning objects. LCMS structure can be observed as upgraded CMS structure extended with *Content Management System* (CMS) [illegible] Ob... [illegible] (RLO) (Nichani, 2001). Term CMS comes from on-line publishing industry and enables creating and administering different contents (articles, reportages, pictures, etc.). CMS article is made of many knowledge grains called content components and they guarantee reusability. One component can be included in many articles which can afterwards be read by many readers. When compared to learning, we work with reusable learning objects that can be used in different domain knowledge and by different students. This reusability and content structuring is employed in LCMS. Content component in learning domain is called reusable learning object.

In spite of numerous definitions for reusable learning objects we cannot avoid having impression that essence is in applying object-oriented model of conception in the "learning world". Alike LEGO blocks, learning objects are reusable components (knowledge grains) – text, presentation, animation, picture, HTML document, used not for building fairytale castles but for knowledge building and acquisition. According to ASTD, learning object is reusable medium independent information used as building block for subject matter in e-learning systems. Learning objects are more efficient if they are organized and qualified by using metadata and stored in data repositories like those in LCMS. IEEE Learning Technology Standards Committee – IEEE LTSC (*ltsc.ieee.org*) defines *learning object* as: „*...an entity, in digital or non-digital form, that can be used, reused or referenced during subject matter ...*". Ministry of Defence of USA and White House Office of Science and Technology at the end of 1997 started an initiative called Advanced Distributed Learning - ADL (*www.adlnet.org*) for the advancement of information and communication technology application in learning and teaching and they proposed standardization of subject matter, so called SCORM model. Structure component is learning object, so called Sharable Content Object (SCO) along with its attributes: reusability, durability, accessibility and interoperability.

... Standards for designing e-learning systems architectures

Alike initiatives in other areas, standards applied in learning technologies should enable reusability and interoperability among different platforms. To accomplish that reusability and operability, consensus in *architecture, services, protocols, data models and open interfaces* should be made. This task is difficult and overwhelming because of the development of learning technologies infrastructure which has its historical dimension and in the last decades was associated with development of computer systems. It presented difficulty to interoperability because, with time, different platforms and architectures were more "fashionable", and speaking in technological sense they depended on era they were developed in. Dynamic development present in the last few years constantly brings up new recommendations, and, as a consequence, there is a steady progress in designing, development and application of learning and teaching systems' architecture standards. E-learning systems' architecture is designed according to the three-tiered architecture made of data tier, application tier and user interface tier (see Fig. 1 modified according to Anido-Rifón et al., 2002).

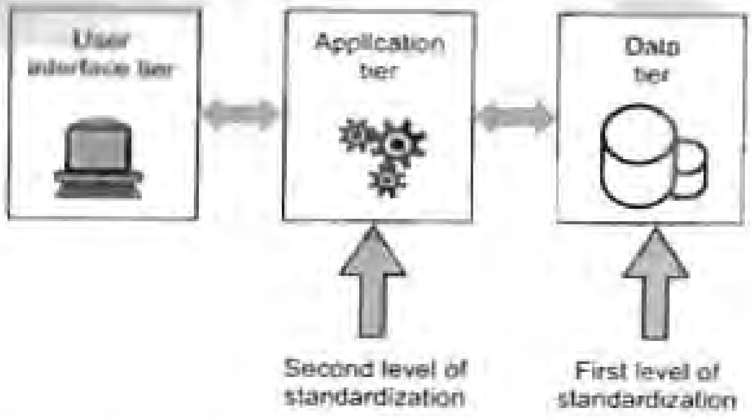

Fig. 1. Three-tiered architecture and levels of standardization

i) – First level of standardization – data model

The most mature results are achieved on the first level of standardization. In most cases XML (eXtend Markup Language) is used for defining information model which enables WWW interoperability.

At this level, standards can be seen as common specification that has to be used by different learning objects vendors which create learning objects by using different systems for supporting learning and teaching process. Relevant specifications on the first level of the three-tiered architecture standardization are: (i) *Metadata* used for precise description of a subject matter. The most notable contribution in this field is done by IEEE LTSC (*ltsc.ieee.org*) in a form of Learning Object Metadata (LOM) standard specification considered to be de-facto standard. This field is believed to be one of the most active parts of standardization process. (ii) *Profile and student record* that present information about knowledge and preferences included in learning and teaching process. IEEE LTSC Public and Private Information (PAPI) specification describes student's record. (iii) *Organization of subject matter* is oriented on description of a course structure that can be static or dynamic. Static course structure defines a priori relations inside subject matter structure (lessons, paragraphs, assignments...). Dynamic course structure determines certain sequence depending on student her/himself and his/her previous interactions with subject matter. This information is used in learning and teaching environment in order to create future student's activities. Predominated standards for organization of subject matter are based on AICC (*www.aicc.org*) and ADL SCORM (*www.adlnet.org*).

ii) – Second level of standardization – common software components and open architecture

On this level standard defines expected behaviour of system components responsible for learning object management in on-line environment. System interface enables construction of new educational systems avoiding building them from start and through improvisations, and besides that, it enables interoperability among systems with different platforms (different operating systems). Nowadays, not many institutions have developed architecture with common components that enable generic learning environment. In respect to the management and administration we have identified three learning system categories: (i) *Educational delivery systems* or support for accessing subject matter by using Web. These systems do not require performance measuring and learner administration. The representative of these systems is Placeware Auditorium (*www.placeware.com*). (ii) *Computer managed instruction systems* that include: subject matter delivery, integrated system for tracking and measuring achievements during learning and teaching process, individual or group work. The representative of these systems is WebCT (*www.webct.com*). (iii) *Learning management systems* were discussed in previous paragraph. One of the representatives of these systems are Docent (*www.docent.com*) and ISOPIA that is considered to be an intelligent learning management system (www.isopia.com).

3. Pedagogic paradigm of e-learning

In period between 1982. and 1984. Anania and Burke at the University of Chicago in USA had conducted a research in which they compared three ways of learning the subject matter: (i) *Conventional learning* where group of 30 students lead by one teacher had to master certain domain knowledge. Students' knowledge was examined through few tests that were used in gaining final mark. (ii) *Mastery learning* where group of 30 students lead by one teacher had to master certain domain knowledge. However, tests were used as a feedback and every test was followed by procedures for correcting way and pace of presentation of a new domain knowledge. (iii) *Tutoring learning* where students master certain domain knowledge guided by personal tutor (one teacher lead one to three students). This way of learning is followed by periodic tests, corrective procedures, feedback and parallel testing as in mastery learning. It is important to propound that need for corrective procedures in this way of learning is very small (Bloom, 1984). Using a standard deviation, it was found that an average student in tutoring group was about two standard deviation more successful than average student in control group (the average tutored student was at a level above approximately 98% of the conventionally instructed students). An average student in mastery learning group was about one standard deviation more successful than average student in control group (the average student under mastery learning attained final achievement above approximately 84% of the students in conventional group instruction). Tutoring learning showed that the majority of students had potential to reach this high level of achievement. An important task of this research was to find ways of accomplishing this high level of achievement under more practical and real conditions than too expensive one-to-

one tutoring. This is known as *2 sigma problem*. Numerous researches tried to determine if, and in what measure, computers and related technologies can contribute to students' knowledge and skills acquisition improvement. One of those researches (Fletcher, 2003) is specific because it is oriented on collecting and systematization of other case studies related in students' achievements in learning and teaching process by using information and communication technology.

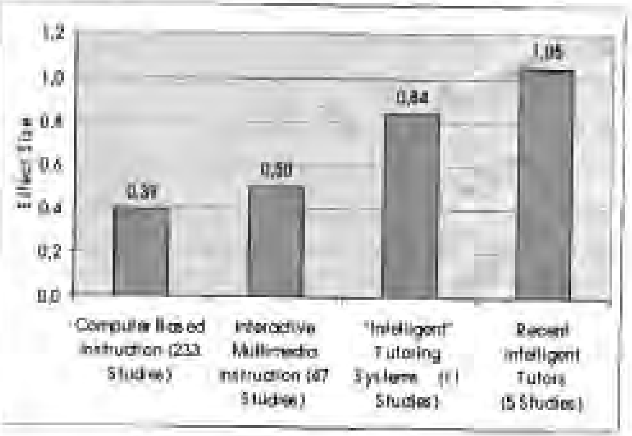

Fig. 2. Some Effect Sizes for Technology-Based Instruction

The research has determined following facts (see Fig. 2.): (i) achievements of an average student in traditional classroom (so called 50 percent student) are equal to achievements of 64% students (64 percent student) who used computers with simple user interface and that improvement was presented with standard deviation of about 0.39 sigma, (ii) students who used computers with interactive multimedia (integrated pictures, sounds and animations) showed achievement effect of 60%, and that improvement was presented with standard deviation of about 0.50 sigma, (iii) students who used intelligent tutoring systems showed achievement effect of 80%, and that improvement was presented with standard deviation of 0.84 sigma, (iv) students who used resent intelligent tutoring systems showed achievement effect of 85%, and that improvement was presented with standard deviation of 1.05 sigma. Fletcher concludes that effect of traditional tutoring learning has not yet been reached, but results are promising.

Intelligent tutoring systems

Intelligent tutoring systems are generation of computer systems aimed to support and improve learning and teaching process in certain domain knowledge, considering individuality of a student like in traditional one-to-one learning and teaching process. Using the results of researches as well as the experience in applying hypermedial authoring shell TEx-Sys and its distributed version DTEx-Sys, that are both based on cybernetic system model (Pask, 1965; Wiener, 1948; Božičević, 1981), we have approached to development of *Web oriented intelligent authoring*

shell called xTEx-Sys, which is extended with some new actors and functionalities (Stankov, 2003). *Web oriented intelligent authoring shell* will have the following actors: (i) students who will be involved in knowledge and skills acquisition process, (ii) domain knowledge experts who will create knowledge bases, (iii) teachers who will didactically design subject matter by using created knowledge bases, and finally (iv) system administrator who will monitor system, users and ways of using system. Furthermore, all users' categories will be able to cooperate while creating knowledge bases or during learning and teaching process in certain domain knowledge. Final phase of the project will include some trial assessment with all student categories: high school students (especially those in final grade for their preparation and selection of college), (ii) university and college students, and (iii) teachers who attend complementary courses during their long-life education related to applying information and education technology in subject matter realization. During our work on this project we have defined following functionalities of xTEx-Sys: user login into system, learning and teaching, knowledge testing using overlay method, knowledge testing using quiz, domain knowledge design, subject matter design, adding users into system (different categories of students, teacher and domain knowledge expert), user overview, changing data about user, adding group of users into system, user group overview, changing data about user group, adding users into user group, adding teachers to user group or individual user, adding courses to user group or individual user, user collaboration (e-mail and on-line textual conference - chat) and finally system administration.

Finally, we present description of a subject matter design functionality that is presented by teacher during creation of her/his course structure. Courseware is internationally accepted term for subject matter designer for execution on computer. Subject matter is defined for certain course that is related to a certain student group. Courseware has multilayer structure consisted of: *units*, *lessons*, *topics*, *instructional items* and *tests of quiz type* (TQ). These elements of courseware structure have been identified according to our pedagogical tradition extended by one new expression, an instructional item, which is considered to be undividable element of subject matter. We want to indicate that undividable element of subject matter is in its essence subject matter object, that is, previously mentioned SCO according to SCORM model. A unit in principle includes more lessons, a lesson includes more topics and finally a topic includes more instructional items. Test of quiz type is appointed to a unit, a lesson or a topic. Teachers freely design the courseware structure, and it includes both vertical and horizontal decomposition of subject matter elements structure. That means that courseware, being built by a teacher, has a tree structure and its elements can be sequenced. Nodes of courseware structure tree are subject matter elements, and they are divided into four levels: (i) first level - *a unit*; (ii) second level - *a lesson*; (iii) third level - *a topic*; (iv) fourth level - *an instructional item*. Tests of quiz type are specially considered to be appointed to every subject matter element except instructional item. Quiz testing can be done in two ways: for testing using static questions generated by teacher and for testing using dynamic questions generated by computer employing randomized selection applied on domain knowledge base. Total number of questions during

...ame is defined by the teacher. Questions, that are related to a set of knowledge ...odes appointed to certain subject matter element, are combined into pairs (two ...uestions in every cycle), and number of cycles is defined by teacher for every sub- ...ect matter structure element that is a test of quiz type.

...he xTEx-Sys is developed by using an object-oriented methodology of software ...ngineering called Rational Unified Process, and tools for visual modelling and im- ...lementation Rational Rose and Unified Modelling Language. Implementation is ...ased on the .Net technology and Microsoft SQL Server system for the managing ...ata bases.

... Conclusion

E-learning presents intersection between the world of information and communica- ...ion technology and the world of education. This fact is valuable particularly when ...t is used as a part of a well planed and organized learning environment, however e- ...earning is not a "magic ball" that will replace existing pedagogical theories, princi- ...les and standards. E-learning is a new learning paradigm based on the electronic ...echnology related, as we see it, with individualized learning and teaching paradigm ...hat relies itself on intelligent tutoring systems. We have presented e-learning as an ...utcome of a modern information and communication technology and we have ...ointed out some configurations (LMS and LCMS systems) and standards for de- ...igning e-learning systems architecture. Standards for designing both e-learning ...ystems architecture (three-tiered architecture) and subject matter (sharable content ...bjects) presented on those systems, will contribute to the clarification of this area ...nd maybe, at this point, after more than fifty years, make computer technologies ...pplication in education a real contribution to didactic and methodical subject mat- ...r design and new knowledge acquisition. New knowledge acquisition nowadays is ...f great significance for success of the individuals as well as society.

References

...ALT (2004) Centre for Studies in Advanced Learning technologies, Lancaster University <http://csalt.lancs.ac.uk/ alt/>. Accessed 14.05.2004.

Anido-Rifón L., Fernández-Iglesias M. J., Caeiro-Rodríguez M., Santos-Gago J. M., Rodríguez-Estévez J., Llamas-Nistal M. (2002) A Step ahead in E-learning Standardization: Building Learning Systems from Reusable and Interoperable Software Components, *The Eleventh International World Wide Web Conference* Honolulu, Hawaii, USA, 7-11 May 2002. <http:// www2002.org>. Accessed 20.01.2004.

ASTD (2001) A Vision of E-Learning for America's Workforce, *Report of the Commission on Technology and Adult Learning* <http://www.astd.org>. Accessed 20.01.2004.

Bloom B. S. (1984) The Two-Sigma Problem: The Search for Methods of Group Instruction as Effective as One-to-One Tutoring, *Educational Researcher*, 13:4-16

...ć J. (2001): Why do we support system approach? *System thinking*, Croatian systems society, Zagreb (in Croatian)

...ić I. and others (2001) Strategy for development of Croatia, *Project task: Information and communication technology*, (in Croatian) <http://www.hrvatska21.hr/ informac.htm>. Accessed 14.05.2004.

Fletcher J. D. (2003) Evidence for Learning From Technology-Assisted Instruction in edition by H. F. O'Neil, Jr., R. S. Perez: *Technology Applications in Education - A Learning View*, Lawrence Erlbaum Ass. Publishers, Mahwah, New Jersey

IsoDynamic (2002) E-Learning - A *White Paper from IsoDynamic* <http://www.isodynamic.com>. Accessed 14.05.2004.

...B. (1997) Advanced Educational Technologies: The Learning Environment, Computers and Human Behaviour, 13,4, 1997.

...B. H. (2001) A Framework for E-Learning <http://www.bookstoread.com/framework/>. Accessed 14.05.2004.

...M. (2001) LCMS = LMS + CMS (RLOs), *Elearningpost* <http://www.elearningpost.com/features/ archives/001022.asp>. Accessed 14.05.2004.

...(1965) A cybernetic model of concept learning, *Proceedings of 3rd Congress International Assoc. Cybernetics*, Namur 1961, Gauthier-Villars

...M. (2000) Establishing of Distance Education Systems within the Information Infrastructure, M.Sc. Thesis, Faculty of Electrical Engineering and Computing, University of Zagreb, Zagreb, Croatia (in Croatian).

SCORM (2003): Advanced Distributed Learning, Sharable Content Object Reference Model, *Best Practices Guide for Content Developers, 1st Edition* <http://www.adlnet.org>. Accessed 14.05.2004

Stankov S. (1997) Isomorphic Model of the System as the Basis of Teaching Control Principles in an Intelligent Tutoring System, PhD Diss, Faculty of Electrical Engineering, Mechanical Engineering and Naval Architecture, University of Split, Split, Croatia, (in Croatian)

Stankov S. (2002) Principal Investigating Project 0177110 *Computational and didactical aspects of intelligent authoring tools in education*, Ministry of Science and Technology of the Republic of Croatia, 2002-2005.

Stankov S. (2003) Principal Investigating Project TP-02/0177-01 *Web oriented intelligent hypermedial authoring shell*, Ministry of Science and Technology of the Republic of Croatia, 2003-2005.

Stankov S., Glavinić V., Granić A. and Rosić M. (2002) Intelligent tutoring systems - research, development and application, *CARNet - Journal Edupoint*, Zagreb, II/1,2,3 (in Croatian)

Stankov S., Glavinić V., Granić A. and Rosić M. (2003) Intelligent tutoring systems - research, development and application, *Collection of papers of Faculty of Natural Sciences and Mathematics and Education, University of Split*, Split, pp. 45-72. (in Croatian)

Wiener N. (1948) Cybernetics or Control and Communication in the Animal and the Machine, M.I.T. Press, Cambridge, MA