# PREFACE

This book tries to stress the importance of synergistic interaction between e-business and e-education, in the context of new Internet related developments. Although the two, e-business and e-education, can co-exist independently of each other, their synergistic interaction is crucial for the process of the Internet-based technology transfer, which is stressed in the foreword contributed by Professor Bob Richardson, a Nobel Laureate from Cornell University. E-business can help e-education, and vice versa, and both can help the acceleration of global technology transfer.

The book also stresses the importance of the globalization issues, and an effort was made to bring together researchers from a variety of geographical locations; mostly young and promising ones, in order to help them obtain a better visibility for their on-going research efforts. Most of the work published in this book was first presented at the SSGRR-2000 - an international conference specializing in the infrastructure for e-business, e-education, and e-science on the Internet (http://www.ssgrr.it/en/ssgrr2000/index.htm) held at Scuola Superiore Guglielmo Reiss Romoli (SSGRR), the Education Centre of the Telecom Italia Group of Companies.

Editors are especially thankful to those who helped this book become a successful reality. Professor Beverly Park Woolf contributed to the selection process. Professor Borko Furht contributed with a plethora of extremely useful suggestions. Cesira Verticchio (SSGRR) helped in the final book preparation stages, while numerous students from the University of Belgrade helped search the World for promising research contributions that make potential candidates for such an edition, to name just a few: Zoran Horvat, Dusan Dingarac, Miodrag Stefanovic, and Marjan Mihanovic.

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*Prior to founding TechnologyConnect, Ms. Chin was the Managing Director of a Hutchison Whampoa backed start up in China which provided the first electronic commerce services in the region. During her tenure, Ms. Chin designed the company organizational structure, developed human resources and financial policies, and established the company by hiring local staff.*

*Before that, Ms. Chin was the Executive Director of Pyramid Technology Corporation, a Siemens Nixdorf Company in the Asia Pacific region now named Siemens Information Systems. At Pyramid Technology, she held P&L responsibility for Pyramid's computer line of business with key focus in data warehouse projects within the telecom and finance industries. In that capacity, Ms. Chin worked with (and educated) customers in different Asian countries to implement data warehouse projects. She also set up infrastructure by establishing partnerships with local companies and hiring both sales and technical people to support the selling efforts. Prior to joining Pyramid Technology, Ms. Chin was the Director of Telecommunications Industry Marketing with AT&T Global Information Solutions (NCR) in the Asia Pacific Area where she was responsible for sales and marketing of data warehouse and billing solutions. Formerly, she was Product Manager, AT&T Network Systems Group (Now Lucent Technology) where she supported sales & marketing, and implementation of more than $16 million of contracts in several Asian countries. Ms. Chin started her career as a Member of Technical Staff with AT&T Bell Laboratories where she designed and implemented different systems ranging from imaging platforms to multi-location video conferencing devices.*

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*Engineering Faculties of the University of L'Aquila, Italy. He still serves as Program chairman, Session Chairman and International Programme Committee member for many International Conferences and Workshops; he also served as keynote speaker for many international events (Nokia and VTT Electronics Summer School, Moscow University, University of Belgrade, Ecole Nationale Supérieure des Telecommunications, etc.). Since 1997 he is the Italian Director for industry of the Euromicro European association. Throughout 1997 he consulted Motorola SATCOM (SATellite COMmunications Division, Phoenix, AZ) concerning the design of the phase III Iridium training courses.*

*He wrote dozens of papers for International Conferences. Since 2000, he is also a member of the Board of Directors and Vice Chairman of Euroteam, an International organisation grouping all the major European Telecommunication Operators. Frédéric Patricelli speaks Italian, French, English and Spanish fluently, he also studied German for 8 years.*

**VELJKO MILUTINOVIC**

*Dr. Milutinovic was responsible for a number of successful commercial products and scientific prototypes (as a designer, architect, or project leader); these include the world's first multimicroprocessor HF radio modem for defence applications (in 70s), the world's first 200MHz RISC microprocessor for DARPA (in 80s), the world's fastest I/O pump for personal computers (PCs) in cooperation with Encore, a clone of Intel i860 in cooperation with Unisys Tokyo, and a number of innovations related to the multimedia PC of NCR (all in 90's). Most recently he is active in infrastructure for e-business on the Internet, where he combines his expertise in hardware, software, and business administration (for more efficient proxy caching, intelligent search, and business automation using the Internet). He is on the Advisory Board of TechnologyConnect from Boston, Massachusetts (www.technologyconnect.com), on the Advisory Board of BioPop from Charlotte, North Carolina (www.biopop.com), and he consulted for a large number of high tech companies including, but not limited to: Intel, Fairchild, Honeywell, Compaq, Encore, Philips, IBM, GE, RCA, NCR, AT+T, QSI, DEC, DELCO,Aerospace Corporation, Electrospace Corporation, Zycad, Virtual, MainStreetNetworks, eT, Marubeni, Unisys, CNUCE and SSGRR.*

*Dr. Milutinovic was on various faculty positions at Purdue University for about a decade back in 80s, and he lectured also on all remaining top 10 US schools in electrical and computer engineering (MIT, Stanford, Berkeley, etc.). While at Purdue, he invented the concept of high-level language architecture based on the principle of vertical migration, the concept of delayed decision computer architecture, and the concept of weighted partial detection architecture - all of them referenced in the open literature and used by industry worldwide. He was also on various faculty positions at the University of Belgrade during the decade of 90s, and he still teaches and conducts research there in the field of infrastructure for e-business on the Internet and computer architecture/design. While in Belgrade, he invented the concept of split spatial/temporal cache architecture, the concept of spacial/temporal mutation in* *genetic search algorithms, and the concept of customer satisfaction/profile/behaviour search based on reconfigurable accelerators and ad-hoc networking. He taught and conducted research also at a number of universities in Italy, Spain, Germany, Mexico, Japan, and Australia.*

*Dr. Milutinovic published over 20 books with the major US publishers featuring a rigorous reviewing process (Wiley, Prentice-Hall, North-Holland, Kluwer, McGraw-Hill, IEEE Computer Society Press, etc...). Some of his books were the best sellers for their publishers (one of them was the best seller of all times for the IEEE CS Press), and for three of them forewords were written by three Nobel Laureates. He published about 50 papers in the world's most prestigeous IEEE journals and about 100 journal papers in total, plus many more at conferences. He was the guest editor for major IEEE journals in computing: IEEE Transactions on Computers, IEEE Computer Magazine, IEEE Concurrency, and Proceedings of the IEEE. His work is extensively referenced in the open literature (over 300 citations untill the year 2000).*

*Dr. Milutinovic presented over 300 invited lectures worldwide (keynotes or tutorials on the opening days of conferences, courses for graduate programs of universities, and consulting reports for industry). These lectures were presented in 10 different languages.*

# Chapter 1

# A DIGITAL MARKETPLACE FOR EDUCATION

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**Abstract** We describe a web-based Educational MarketPlace that matches student requests for learning materials to available and appropriate resources. We address technical issues such as: 1) resource acquisition and data mining techniques to facilitate access to large-scale educational repositories; 2) negotiation, contract execution and verification of instructional resources, and 3) digital repository testbeds to evaluate agent behavior. Societal issues include understanding web-based educational interactions, individual learning processes and organizational dynamics in the distributed, digital instructional realm. The Educational MarketPlace is different from other Internet spaces in that it requires independent scoring of resources and certification of teaching. This chapter discusses these issues and the open learning environment where a learner has choices; it describes how the Internet might replace the existing education monopoly and help dissolve the cottage industry of education in which a teacher handcrafts materials fixed by space and time.

## 1 PROBLEM STATEMENT

Many problems prevent people from obtaining maximal benefit from the Internet. Numerous resources exist, characterized by a great diversity in cost, prerequisites, quality, approach and availability. However, people cannot comprehend nor fully exploit the huge amount of available on-line knowledge; it surpasses the ability of people to locate, evaluate or manipulate. Thousands of resources exist and the environment is in constant flux, see Table 1. Currently, some resources might provide formal credentials, others simple knowledge and still others experience or training. The material varies in pedagogy and interactivity from intelligent tutors [Woolf & Hall, 1995; Beck et al., 2000], to simulations, hypermedia [Brusilovsky, 2000] and papers.

*Table 1.* Web-based Instructional Resources

| **Educational Resources on the Web** |
|---|
| COURSES:<br>E-College, www.ecollege.com, thousands of courses, one hundred degree programs<br>CaliforniaVirtual University, www.cvc.edu, 1569 courses.<br>Western Governor's University, www.wgu.edu, 275 courses.<br>Southern Regional Education, www.-srec.sreb.org, 300 courses |
| OBJECTS:<br>Educational Object Economy, www.eoe.org, 2600 learning objects<br>NEEDS engineering database, www.needs.org, 863 Modules |
| INSTRUCTIONAL LIBRARIES:<br>Chemistry, www.chem.ucla.edu/chempointers.html<br>Mathematics, www.forum.swarthmore.edu |
| DATABASES<br>NASA, www.nasa.gov/gallery/index.html<br>Human Genome, www.ncbi.nlm.hih.gov/genemap99 |
| CLEARING HOUSES, PORTALS, CHANNELS<br>American Distance Education Consortium,www.deal.unl.edu<br>The Gateway to Educational Materials, www.thegateway.org,<br>Ask-ERIC, www.askeric.org<br>Advanced Distributed Learning www.adlnet.org |

For example, more than 27,000 college-level courses were delivered over the Internet and more than 1.6 million students enrolled in a distance education course in 1997-1998 [Boettcher, 2000]. Additionally, 53% of U.S. colleges offered distance education courses and an estimated 1,230 degree programs were designed to be completed totally through distance education. The number of institutions using Internet technologies tripled in the last three years and 82% of institutions queried said they would start using this method or increase their use of this method over the next three years [Boettcher, 2000]. As these numbers increase serious problems of efficiency will develop unless novel mechanisms are implemented to manage the resources and interaction.

In a well managed educational network, tools are needed to organize and manage these resources. For instance, a query from a student changing majors might elicit a schedule of tailored resources, containing only that student's course deficiencies, a pre-medical student might receive a college course, combined with quizzing module and real-time experimental-data, and a visually handicapped student might receive only spoken software. The educational network should use student modeling and machine learning techniques to assemble and tailor resources. The student should be able to access classes of objects, distributed across heterogeneous repositories and customized by mediating software that compensates for site-by-site variations.

## 2 EDUCATION AS E-COMMERCE

Universities enjoy a monopoly on higher education, which is maintained as a cottage industry, with faulty handcrafting courses from scratch and delivering made-to-order programs to an audience fixed in time and space. Constraints of geography and time and certification through awarding degrees have reinforced this monopoly [Dunderstadt, 1997].

The tremendous impact of the Internet is helping dissolve this monopoly, while eliminating the constraints of time and space. It is creating open learning environments in which the learner has a choice in the marketplace. Individual handcrafted courses are being challenged by the increasing demand for advanced education and the expanding digital environment, which attracts new competitors, exploiting new paradigms and threatening traditional providers.

Through the Internet, education will become learner- and goal-oriented rather than faculty-centered. Evolution towards the learner is both evident and irresistible [Dunderstadt, 1997]. Why would students choose to take classes from the local professor when they can take classes with global experts? The outstanding local professor, teaching a unique or hands-on course or providing a strong experience, will continue to draw a following. However, other types of learning will become a "commodity" provided to anyone anywhere for a price. In effect, the customer pull (student demand) will obtain effective influence over a market that for 600 years has been shaped only by producer push (instructor offerings).

Most faculty are not adept at "packaging" content for mass audiences, even though some write textbooks, which are typically marketed and distributed by publishers. Faculty are skilled at creating content for their lecture-based programs. Universities have begun to use the web to outsource production and distribution of courses by those most experienced in reaching large populations of students.

Higher education in the U.S.A. is already a $175 billion-a-year enterprise and has spawned new players such as virtual universities and for-profit organizations to take advantage of the market interest [Dunderstadt, 1997]. Like other "deregulated" industries, e.g., healthcare or communications, education is evolving. As the global society becomes ever more dependent upon new knowledge, educated people and knowledge workers, the global knowledge business must be viewed as one of the most active growth industries of our times. As a result of E-commerce, higher education is evolving from a loosely federated system of colleges and universities into a global knowledge and learning industry.

From the viewpoint of venture capitalists, education is one of the most fertile new markets for investors. It has a combination of large size (approximately the same size as health care), disgruntled users, lower utilization of technology, an extremely labor intensive workforce and possibly the highest strategic importance of any activity in which global countries engage. Additionally, existing management are sleepy after years of monopoly [Dunderstadt, 1997].

# 3 PROPOSED SOLUTION

Many technical and social barriers need to be addressed before education becomes an open global learning marketplace supported by the web. For example, technology must be developed to harness and structure millions of web-based educational resources. Software must provide accurate and efficient access to large collections of instructional resources. Achieving this requires breakthroughs in the description, representation and retrieval of resources, agent technology, marketplace exception handling mechanisms and student modeling. Issues include assembly and disassembly of resources, negotiation over multi-leveled issues, identification of pedagogical pre- and post-conditions, and creation of student and knowledge models that persist for a lifetime, improve over time and maintain privacy.

We are building an Education Network, or E-Net, that contains classes of agents representing students and resources, see Table 2. These components are described in Section 6. Information retrieval techniques are being integrated into a digital marketplace that represents and delivers instructional

*Table 2.* Components of E-Net

| Component | Target Capability | Technology |
|---|---|---|
| **Student Agents** | Monitor course plans, record student model, interact with student and supervise negotiation. | Student modeling in interactive systems |
| Search Bots (SB) | Search web for pedagogical agents; standardize terms. | Information retrieval |
| Course Assembly (CAA) | Assemble and build plans from resources offered by other agents. Negotiate, collect bids, form contracts. | Planners, fuzzy operators; machine learning |
| **Pedagogical Agents** | Represent instructional resources. Negotiate contracts with student agents. | Pedagogical modeling, economic modeling |
| Resource Agents (RA) | Provide wrappers for one or more resources. | Provide a set of simple shells for wrapping common types of resources. |
| Resource Classifiers (RC) | Creates models of resources using standards to enable resources to be wrapped. | Machine learning to gauge effectiveness of resources, reduce overtime; Automatically find pre- and post- conditions |
| **MarketPlace** | Enable the assembly of resources. | Manage large dynamic open systems; develop market institutions; help anticipate, avoid and detect non-compliant resources. |

material, manages the tangled web of resources and students and respects the privacy of students. Authors of educational resources will be encouraged to contact E-Net to register their resources into the marketplace, but E-Net will also actively search for and incorporate resources without any specific action by developers.

E-Net will dynamically support learners in the selection and management of instructional resources. It will enable students to better exploit the vast quantity of knowledge distributed across the Internet. E-Net will accept queries of three types: Level 1: Classical course request–"I need to refresh my calculus in preparation for the physics 101 course next week." Level 2: Multi-disciplinary query–" I want a summer long course in biomedical engineering." Level 3: Highly focused topic–"I need to model turbulence using computational fluid dynamics."

# 4 EXISTING SOLUTIONS TO THE PROBLEM

No current research addresses these concerns. Many commercial and academic organizations have built thousands of web resources characterized by student age, cost, learning types, etc. (see Table 1), but no technology exists to search, retrieve, tailor, schedule, deliver and evaluate resources within a standardized environment with a safety net provided by the marketplace.

Many Internet marketplaces exist. However, this marketplace is different requiring several new components and capabilities.

1) Independent Scoring of Resources. The typical virtual marketplace does not distinguish between agents of greater or lesser use – all goods and services with the same description are assumed to be identical for the purposes of matchmaking between the constituent agents. This may be acceptable where the goods of trade, such as cars or airplane tickets, are in fact interchangeable, or at least where the differences can be tolerated; but where this is not the case, exception handling is needed. The instructional marketplace will provide a mechanism for differentiating between educational resources with similar descriptions on the basis of their performance. In most cases the educational resources will be scored automatically by the system, based on information provided by the other resources that interact with the same student.

2) Certification/Reputation Agency. Current marketplaces accept all new resources. The education marketplace can only support certified resources. To allow student agents to confidently contract with new resources, the instructional marketplace will provide a certification service whereby any new active tutoring system will require an endorsement by independent human professionals. (For example, two or three endorsements by teachers who use the service.)

3) Contract Fulfillment. In a perfect world we can rely on agents to be honest and always tell the full truth; in the real world, and particularly where

Chapter 2

# INFORMATION TEACHNOLOGY:
*Using the Internet for Student Research*

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**Abstract** In the rush to adopt Internet technologies, many schools have underestimated the need for human infrastructure. Experienced educators know that we must add an "A" to "tech"; technology in isolation ignores the "A" in "teAch."

To conduct research on the Internet, students must learn to navigate skilfully by using subject directories and search engines. It is imperative that students and teachers examine information sources with a critical eye, evaluating their authority, accuracy, objectivity, currency and relevance. Teachers must also reconsider the design of their research assignments so that they promote original thinking through synthesizing a variety of materials while avoiding Internet-fostered plagiarism.

**Key words:** Information literacy, information retrieval, information skills, Internet, secondary school curriculum, World Wide Web

## 1 INTRODUCTION

Clifford Stoll, self-proclaimed High Tech Heretic, "assails high-tech boosterism, attacking the trendy assumption that computers will profoundly improve our schools, libraries, and whole society."[1] In the rush to adopt new technologies, schools and districts have too often ignored the simple fact that machines do not change teaching and learning. People do. Experienced educators know that we must add an "A" to "tech"; technology in isolation ignores the "A" in "teAch."[2]

[1] Kirkus Reviews of High Tech Heretic by Clifford Stoll [Doubleday, 2000].
[2] Janet Murray, "From School Librarian to Information TeAchnician: A Challenge for the Information Age," Library Talk. Worthington, OH: Linworth, May 1999, pp. 10-13.

## 2 PROBLEM STATEMENT

The CEO Forum, a national group of U.S. business leaders, reported that "although there are more than 6 million computers in the nation's schools, most teachers lack the training to use them effectively. Why? Because . . . schools are spending less than $6 per student on the computer training of teachers, contrasted with more than $88 per student on computers, computer programs and network connections."[3] In the American idiom, this is known as "putting the cart before the horse."

Henry Jay Becker's national survey, "Teaching, Learning and Computing: 1998," supports the CEO Forum's conclusions. "We found that 90% of all U.S. schools have some kind of access to the Internet. What is so remarkable about this statistic is that most schools, which historically change so slowly, have made this connection within just 5 years."[4] However, Becker's study also reveals the need for professional development appropriate to the integration of technology in the classroom.

In 1997, the U.S. President's Committee of Advisors on Science and Technology (PCAST) observed that, "The benefit to students increasingly will depend on the skill with which some three million teachers are able to use these new tools."[5]

> Although 95 percent of American schools now have Internet access, many teachers still do not know how to use the tools or do not feel comfortable using the technology in their classrooms. According to a survey by Market Data Retrieval, 61 percent of teachers in elementary or secondary schools consider themselves "somewhat prepared" or "not at all prepared" to incorporate technology into their lessons. Many of these teachers feel intimidated by having computers in their classrooms, especially when their students may have more computer experience than they do, while other teachers simply do not think computers add anything to the educational process.[6]

A business-oriented publication expressed its concern in September, 2000.

3 "Inadequate Computer Training for Nation's Teachers," Associated Press, February 1999.

4 Ronald E. Anderson and Amy Ronnkvist, "The Presence of Computers in American Schools," Teaching, Learning and Computing: 1998: A National Survey of Schools and Teachers. Center for Research on Information Technology and Organizations. June 1, 1999. http://www.crito.uci.edu/tlc/findings/computers_in_american_schools

5 "President's Committee of Advisors on Science and Technology (PCAST): Its Report on Technology in Education," FYI #107: Education Technology Report FYI, The American Institute of Physics Bulletin of Science Policy News Number 107, September 4, 1997. http://members.stratos.net/aw/tech.pcast.htm

6 "As Computers Idle in Classrooms, Training for Teachers is the Next Challenge," New York Times, July 3, 2000, quoted in Edupage, July 3, 2000.

> Digital educational tools in public schools across the country may prove to be a disappointment if educators are unable to incorporate the technology into their curriculum. Getting the most out of computers and Internet access in schools is a major challenge for teachers because many do not have the skills to use the technology effectively.[7]

Ken Wasch, president of the Software & Information Industry Association, concludes,

> Technology improves teaching and learning, but the simple addition of computers in schools does not directly translate to higher test scores and never will. From the school board and district administrators to principals and teachers, setting the right conditions and thorough training are the two most important keys to success. In this sense, the process of technology integration into the curriculum is just as important as the technology itself.[8]

The "2000 Report on the Effectiveness of Technology in Schools" concurs with the statement that the "leading variable" influencing the effectiveness of education technology is educator training. Teachers would argue that society has unfairly burdened them with the responsibility for implementing technology without providing adequate opportunities to learn the necessary skills.

> According to Education Week's third annual study of the state of technology in schools, "Even when computers are available, teachers said they simply do not have enough time or incentive to use digital content over books and other traditional methods."
>
> "One of our main findings was that most teachers are having trouble finding high-quality software and Web sites," said Erik Fatemi, Education Week's project editor for the report. "It's one thing to train teachers on just the technical aspects of the technology, but it's another thing entirely to teach them how to use that technology effectively in the classroom."[9]

Margaret Honey concludes: "Teachers cannot be expected to learn how to use educational technology in their teaching after a one-time workshop. Teachers need in-depth, sustained assistance not only in the use of the technology but in their efforts to integrate technology into the curriculum."[10]

7 "Technology Savvy Schools," Business 2.0, September, 2000, quoted in Edupage, August 28, 2000.

8 "SIIA Releases Report on Effectiveness of Education Technology," press release 8/24/2000.

9 Courtney Macavinta, "Teachers see major obstacles to wiring schools," Education Week, September 27, 1999.

10 Margaret Honey, Katherine McMillan Culp, and Robert Spielvogel, "Critical Issue: Using Technology to Improve Student Achievement," Center for Children and Technology,

Some entrepreneurs have tried to meet the challenge of inadequate professional development by creating CD-ROM resources and structured sequential courses. Their products may be glitzy and glamorous, and administrators may be tempted to buy them as an "easy" solution. However, any technology offering which ignores the disparity among individuals and the need for ongoing, personal support is likely to be as unsuccessful as the one-time workshop.

Educators need a framework to organize their thinking about integrating technology in the curriculum. Research is traditionally part of the pre-university curriculum. Perhaps we can use the research process to introduce information literacy and technology skills to teachers, and benefit today's students at the same time.

## 3 INFORMATION LITERACY

Traditionally, schools taught the "three R's: reading, 'riting and 'rithmetic." "Literacy" was captured in international census data by estimating the percentage of people who could read and write.

As computers became essential in the workplace and dribbled into schools, "computer literacy" entered the curriculum, usually in the form of an introduction to the new vocabulary of bits and bytes, hardware and software. Computer courses focused on programming languages. "Keyboarding" replaced typing.

### 3.1 Definition

The term "information literacy" first appeared in the mid-1970s as awareness grew that information was becoming an overwhelming and unmanageable deluge. In the 1980s, people realized that computers might be useful tools for organizing and retrieving information. In 1989, the American Library Association codified a definition which provided the basis for subsequent discussion: "To be information literate, a person must be able to recognize when information is needed and have the ability to locate, evaluate, and use effectively the needed information."[11] In other words, "literacy" implies more than vocabulary and awareness; it requires critical thinking.

This connotation of "literacy" – one that includes interpretation and evaluation of a medium of expression – is applied in many different contexts. One reads about visual literacy, media literacy, textual literacy, numerical literacy, technology literacy and network literacy. In each case, the author

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adapted by North Central Regional Technology in Education Consortium, 1999. http://www.ncrel.org/sdrs/areas/issues/methods/technlgy/te800.htm

[11] "Final Report of the American Library Association Presidential Committee on Information Literacy" (1989) quoted in Kathleen L. Spitzer with Michael B. Eisenberg and Carrie A. Lowe, Information Literacy: Essential Skills for the Information Age. Syracuse, N.Y.: ERIC Clearinghouse on Information & Technology, 1998, p. 22.

expects the word "literacy" to suggest a complex of skills, including analysis, evaluation, synthesis and application.

## 3.2 Economic Motivators

Economic forecasters and business analysts predict that 21st century jobs will require information-processing skills. They expect a fundamental shift from production to information management, with a much higher percentage of the workforce employed in service industries. The 1990 report of the Secretary's Commission on Achieving Necessary Skills (SCANS) identifies information and technology as two of the five competencies essential for employment.[12]

> Education is needed to combat high-tech labor shortages, concludes the 21st Century Workforce Commission report. After months of interviews and hearings conducted nationwide, "A Nation of Opportunity" recommends adult learning, early-childhood education initiatives, and regional training programs as a way to foster 21st Century Literacy. Labor analysts warn that the economy will suffer without such literacy, a combination of traditional and technical skills.[13]

Thus, this is not solely an education issue; it is an economic issue. Just as the realities of the workplace dictated the introduction of computers into schools, the needs of the future work force dictate the importance of acquiring information problem-solving skills. In an environment of rapid change, we must provide opportunities and skills for lifelong learning.

> Companies across all industries have come to view e-learning initiatives as essential to continued success. IBM's James Sharpe says "E-learning is one way to be smarter than the competition." IBM's Sharpe says the best e-learning initiatives are those that are integrated with ongoing training processes. Companies are projected to spend $11.5 billion annually on e-learning initiatives by 2003, according to International Data, up from $3 billion spent on e-learning last year.[14]

"Over the next 5 to 10 years, the same technologies that have forced corporations to remake themselves for e-commerce hold the potential to similarly transform U.S. education."[15] But this is not an exclusively American challenge; it is an international challenge. The June 1999, G8 Economic Summit concluded:

[12] Ibid.

[13] "Report Calls for Workforce Education," Washington Post, 27 June 2000, quoted in Edupage, June 28, 2000.

[14] "Online Learning: The Competitive Edge," InformationWeek Online, August 28, 2000, quoted in Edupage, August 28, 2000.

[15] William C. Symonds, "Wired Schools: A technology revolution is about to sweep America's classrooms," Business Week Online, September 25, 2000.

# Chapter 3

# A CONSTRUCTIVIST LEARNING STUDIO BASED ON COGNITIVE TIME ANALYSIS

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## 1 INTRODUCTION

The role AI plays in educational software design and construction is in constant evolution as underlying educational frameworks and paradigms change. Frequent criticisms have arisen with respect to the tutoring-focused, goal-based, knowledge domain transfer, of course material. It has been realized that the modelization of the learning process outweighs the characterization of domain knowledge (Akhras & Self, 1998; Espinosa & Ramos, 1998; Espinosa & Ramos 1999). However, purely instructivist [human, and recently machine] tutors, relying on knowledge transmission, are still mainstream in classrooms around the world (Latchman, Salzman & Gillet, 1999). Therefore, domain models and task models are being *complemented* with cognitive state models (Andriessen & Sandberg, 1999) and expert machines to handle these (Murray, 1999). According to these lines of thought, however, human cognition is only considered as part of ontology when it comes to learning environments where collaboration enters the scene. We maintain that fulfilling pedagogic goals in an Instructivist courseware always motivate the human being to make use of an autonomous cognitive history and data, both of which are *interpreted* in particular ways depending on a person's *singularity* (Espinosa & Ramos, 1996c). However, such behavior cannot be specified as a consistent model, nor is fully formalizable, given its non-predictive, non-monotonic, non-precise, and holistic, nature. Furthermore, sometimes it is not even perceivable, or evident, to the instructor, the student, or the computer software. The reason: in most cases, the core of the instructional design relies on the fact that learning proceeds by tacking, and solving, problems, *correctly*. Pedagogic planning for structured success is an easy solution to formalizing procedural domains (Andriessen & Sandberg, 1999). However, *people learn from their mistakes* (Cox, 1996), which is a far more complex, and non-structured, scenario, because it is a *holistic* one. Reasoning from failure is a cognitive task digging into the very nature of human introspective capability. Non-cartesian qualification of human comprehension is nowadays considered to be a direct result of analysis of the *spoken language*, as well as its decoding, a good reason for attempting to understand how do we understand something. The currently mainstream research strand on tutorial dialogues is based on this fact. Ignoring such cognitive state transformation during single-student performance in front of a computer loaded with educational, hereby called *Learning Studio*, software, is equal to assuming that a default (i.e. ideal) behavior is fully characterizable when performing task modeling on a single person. In our perspective, this does not hold. In contrast, we work in the intersection of behaviorism and cognitive science, and show that monitoring of single-actor activities suffices to *evidence the total/partial existence, or incomplete/flawed occurrence of*, a singularly-generated cognitive learning process evidencing learning. We explain the basis for such an argument in sections 2 and 3.

Our work in Instructivist-applied Constructivist educational software has evolved from the definition of an agent-oriented approach to designing observable and vaguely-interpretable, but non-Constructivist Instructional Graphs called *Educational Measurement Instrument* (EMI) (Espinosa, & Ramos, 1996a; Espinosa, Boumedine & Chirino, 1996b), to the formalization of cognitive phenomena in non-monotonic, and temporal logic terms (Espinosa & Ramos, 1997). The EMI Model monitored instructivist (i.e. behaviorist) interactive course designs that uncovered real patterns of conduct during classroom activities and enabled us to watch for screens and lessons that were incorrectly, partially, or seldom, used, from the Objectivist standpoint. This provided data to help computer tutors compare this conduct to ideal ones. The next step has been to incorporate cognitive capabilities to EMI, thus addressing Constructivism. Cognitive data evidencing unpredictable (i.e. "incorrect") behavior is far harder to discover than ideal behavior, so ontological thinking is required to characterize it, without trying to "mimic" the complete process inside the computer. One reason for this difficulty is that although instructional design, the dominant technique for educative technology, is deeply rooted in behaviorism, ironically tends to hide student learning behavior detail, making it hard to detect key actions which could have led to failure in learning, inherently helping professors guide their students to a better educational situation. We attempt to clarify this phenomenon in section 3. Our assumption is that AI plays a key role in providing for better mechanisms to uncover subtle events in students' conduct, but not to reproduce them in formal terms. In this case, a software agent approach to Temporal Modal Logic engines (to be explained in section 4) served as a vehicle to data-mine an educational studio, or active learning environment, through Cognitive State Modeling. The learning process is thus addressed, although many issues on Instructional Design are still unresolved.

This agent-prone evolution has been clearly consistent with the mainstream in computer-assisted education, as reported in (Andriessen & Sandberg, 1999), in the sense that "intelligent" behavior of a software agent, or similar expert system, has not been proven a conclusive gadget for effective learning outside experimental situations (Derry & Lajoie, 1993). Throughout the process, we have deepened our research into finding ways of discovering, and recording, of the precise moments in time, and their related circumstances, in which the cognitive events leading to a particular student's learning, or knowledge discovery, strategy (i.e. the *Cognitive Equilibration, Contradiction and Structure Construction process*: Twomey, 1996), actually occur. We know that they evolve as constant, dynamic processes, contributing to unique, and sometimes unpredictable, ways of building knowledge. However, given the structure of current educational programs, observation resulting from direct contact with the student is severely limited with respect to the full 24-hour day. Most of the learning process is intractable to the instructor. An automated tool allowing her to *evidence* the learning process, for subsequent (i.e. virtual) personalized tutoring, would thus be desirable. Evidence that such phenomena is actually occurring could be detected by a *Temporal Inference Engine* (TIE) working around the clock, on a distributed media like the Internet. This tool could then be used to help her visualize the learning history of any student, in graphical (VRML-type), temporal (the student entered lesson A *before* lesson B *after* she completed assignment C), and cognitive (she retained the concept of tangent after she abstracted the 3D spatial notion of line), fashion, thus allowing her to *coach* the students more efficiently, and *personally*. A *Constructivist Animated Arena* (CAA: Espinosa & Ramos, 1999) is a learning studio tool that lets the student wander at her own pace so that the goals are reached in [properly limited] holistic manners, which the TIE constantly scans and logs, so that "smart" (not intelligent) monitoring fit well, using temporal modal logic. In a recent publication, Self and Akhras (Self & Akhras, 2000) outline four principal aspects in a comprehensive view of learning from the Constructivist standpoint. These are:

- Context (the social environment in which learning takes place).
- Activity (heavy interaction between the student and the domain studio).
- Cognitive Structures (interpretation of previously constructed knowledge).
- Time-extension (reference framework for the construction to take place).

It is noteworthy that the characterization of the learning process is being tacked by merging human factors such as the context and activity areas, with more philosophical ones such as the cognitive science and reasoning over time structures, specially since many people around the world are reporting that learning actually takes place in environments which allow students to interact among themselves, in situations where the instructor is virtually present, and in virtual scenarios where a strong emphasis on social application context is added to the domain knowledge (Willis & Oman, 2000). We view our CAA, or learning studio, work as covering all four aspects reported by Self and Akhras, but specifically the time-extension and the cognitive structures ones. The reason is that we place special interest in reasoning for incomplete, or flawed, but pedagogically relevant, data. Cognitive structure interpretation comes in handy in these cases, because we will adhere to the Constructivist thesis that "...all observation involves interpretation and that interpretation is influenced by the categories or concepts into which we map or encode our perceptions" (Luger, et. al, 1994). Although this work is not mainstream on interpretation, we make use of a simple scheme to achieve a basic version of it. Section 4 deepens into temporal logics and their implementation in our project as a standing example of direct observation and mapping upon a CAA.

This paper presents partial, and simplified, results of actual classroom behavior upon using our software, and attempts to demonstrate that a mixed approach to virtual education accounts for better results when modeled as CAA. The *Temporal Information Measurement Instrument* (TIMeI) does not attempt to exhibit intelligent behavior. Rather, it concentrates on its role as a TIE that provides useful information to a computerized tutor, or to the human instructor. TIMeI was implemented on the WWW using Java and VRML, plus an inference engine written in Visual Basic. The end-result is the *Constructivist and Open Temporal Inductive Math Environment* (COTIME) program, a Java-VRML system currently used in the High School program at the Montrerrey Institute of Technology in Mexico City. We provide conclusions, limitations on our work, and future trends we will follow using this new technology.

# 2 TEMPORAL HOLES IN INSTRUCTIONAL DESIGN

We now proceed to explain our arguments for using time as the premier ontological vehicle for student learning characterization. As said in the previous section, our reference framework for characterizing the learning process is based on a time-continuum. Consider the Instructional Graph (IG) in Figure 1. Let an interval within an IG be defined by two vertices (i.e. lessons). By making use of Allen's Temporal Logic Relational Operators (Pelavin, 1986), the following holds:

$$\begin{aligned}&\{L_1 before L_2 \bullet before = t_0\} \wedge \\ &\{L_1 before L_3 \bullet before = t_1\} \qquad \bullet = \text{"}where\text{"}\end{aligned} \qquad [2.1]$$

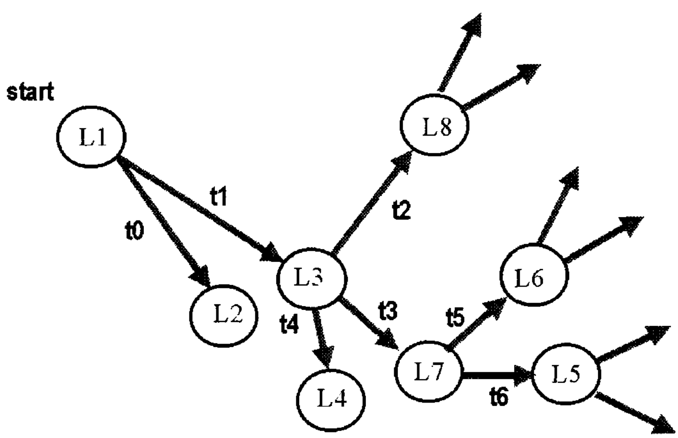


*Figure1:* Temporal holes in Instructional Design.

That is, the temporal description lies within the relation between lessons, so we may monitor when a student has finished a lesson, assuming knowledge and skill acquisition, and passed on to the next. However, the following *does not hold* :

$$\{L_3 beforeL_8 \bullet before = t_2\} \wedge \{L_3 beforeL_7 \bullet before = t_3\} \wedge \\ \{(a_1, a_2, a_3, \mathrm{K}\ , a_k \in Actions) duringL_3\} \qquad [2.2]$$

*Actions* are interpreted as low-level *computer events* taking place as the student makes use of a lesson. We consider low level actions events such as mouse clicks and drags, as described in (Adelheit, Gulla & Thiel, 1997). Now consider that:

$$taughtby\,(L_3, L_1, t_1) \wedge taughtby\,(L_2, L_1, t_0) \wedge \\ usedby\,(L_3, L_8, t_2) \wedge usedby\,(L_3, L_1, t_3) \wedge \\ \langle L_1(o)L_3\rangle \wedge \langle L_3(b)L_7\rangle \wedge \langle L_3(b)L_4\rangle \wedge \langle L_3(b)L_8\rangle \wedge \langle L_2(o)L_3\rangle \qquad [2.3]$$

The temporal relationship

$$\langle L_i(R)L_f \bullet R = \{eq, b, a, d, di, o, oi, m, mi, s, si, f, fi\}\rangle$$

between vertices depicts a structured order of events taking place within the context of the graph. These refer to two or more intervals of time and their occurrence with respect to each other. Let *(t,u)* be fixed points (i.e. instants) in time:

1. (t,u) before (b) (v,w) if u<v.
2. (t,u) meets (m) (v,w) if u=v.
3. (t,u) overlaps (o) (v,w) if t<v<u<w.
4. (t,u) starts (s) (v,w) if t=v & u<w.
5. (t,u) during (d) (v,w) if v<t & u<w.
6. (t,u) finishes (f) (v,w) if v<t & u=w.
7. (t,u) equals (e) (v,w) if t=v & u=w.
8. (t,u) after (a) (v,w) if v>u.
9. (t,u) meets include (mi) (v,w) if u=w.
10. (t,u) overlaps include (oi) (v,w) if v>t & u<w.
11. (t,u) starts include (si) (v,w) if t=v & u>w.
12. (t,u) during include (di) (v,w) if v>t & u>w.
13. (t,u) finishes include (fi) (v,w) if v>t & u=w.

The model was first described in (Allen & Koomen, 1983) and later completed in (Pelavin & Allen, 1986). In our case, consider $\langle L_2(o)L_3\rangle$. This is

Chapter 4

# WEB-BASED ADAPTIVE EDUCATIONAL SYSTEMS

## *Towards an evaluation and design support framework*

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**Abstract** Intelligent Tutoring Systems and the evolution of Adaptive Hypermedia have opened the way for the emergence of Web-based Adaptive Educational Systems (AES). However, AES have not yet been sufficiently tested for ill-structured knowledge domains. In the first part of this chapter we examine the question of applicability of AES for constructivist-oriented instruction in such domains. More specifically, we identify the basic problems related to this question, we analyze them and, for each case, we identify and propose conditions that are instrumental for the implementation of AES for ill-structured domains. In the second part of the chapter, we propose an evaluation and design support framework for AES. The objective of the proposed framework is to help evaluate and design AES that are suitable for ill-structured domains and able to support introductory level learning when needed. The work is based mainly on recommendations from Cognitive Flexibility Theory (CFT) and the Framework for Contextual Analysis of Technology Based Learning Environments. Using these recommendations, we present a three-step approach, according to which we first determine fundamental design decisions, transform these into evaluation criteria and finally evaluate architectural mechanisms of AES against the criteria identified. Efficient architectural mechanisms may be leveraged in the design of new, better AES.

**Key words:** Web-based Adaptive Educational Systems, Ill-structured Knowledge Domains, Cognitive Flexibility Theory

# 1 INTRODUCTION

This chapter begins with the question of *applicability of Web-based Adaptive Educational Systems (AES) for constructivist-oriented instruction when the knowledge domain is ill-structured (e.g. History, Humanities, etc).* The importance of this question is due to the following: (a) The foundation of web-based educational systems is hypertext. However and despite all the hype, effectiveness of hypertext-based instruction has been strongly contested (e.g. [Kotze98]). (b) In addition, a number of reasons for instruction failures in ill-structured domains have been identified (cf. [Spiro96]). Thus, although several AES exist, one can argue that certain problems should be first resolved for efficient application of AES in ill-structured domains. We analyze this question into three basic sub-problems presented in Section 2. For each problem we identify some important issues and produce some initial conclusions for the implementation of AES for ill-structured domains. Hence, this paper proposes that such systems can be suitable, if some basic conditions, reported here, are met. Most of these conditions are of a general nature and independent of a specific instructional theory – they stem from the ill structure of the knowledge domains. In order to define an evaluation framework, we narrow our scope and focus on one theory of instruction, Cognitive Flexibility Theory (CFT). This theory is devised with ill-structured domains and hypertext technology in mind. In Section 3.1 we detail the objectives of the proposed framework and outline a three-stage process for defining the framework. Following this process, in Section 3.2 we organize Hypertext design decisions derived directly from CFT or from implementing adaptive functionalities not inherent in CFT. In Section 3.3, we combine these design decisions with features of AES identified in Section 2. As a case study on the proposed framework, we evaluate two AES, AHA and KBS-Hyperbook, and present the evaluation results in Section 3.4.Part of this work was presented in the 2nd Hellenic Conference with International Participation, Patras, Greece [Papaterpos00].

# 2 SELECTING AES FEATURES SUITABLE FOR ILL-STRUCTURED DOMAINS

## 2.1 AES, Constructivism and Ill-Structured Domains

***Sub-problem A: Are there any characteristics of AES that make them suitable for constructivist instruction in ill-structured domains? What types of AES are more suitable?***

### 2.1.1 Definition of AES

We first need to adopt a definition of AES. We define AES as learning environments (typically hypermedia based) on the web, capable of adapting instruction (e.g. content delivery, user assistance, etc) to the learner's skills, needs and goals. According to [Brusilovsky98a], Web-based Adaptive Educational systems inherit from traditional Intelligent Tutoring Systems (ITSs) and Adaptive Hypermedia Systems (AHSs). ITSs typically partition the information space in knowledge about the domain, knowledge about the user and teaching strategies to support individualized learning. Adaptive Hypermedia Systems typically engage in content and navigation adaptation, altering the link structure and the node contents of the hypertext that contains the educational material. The following classification of AES based on their goal, is due to [Brusilovsky98a]:

- *Curriculum Sequencing (or instructional planning)*: Provide the learner with the most suitable individually planned sequence of knowledge units and learning tasks
- *Intelligent analysis of student solutions:* Identify in the student's solution of a problem what exactly is wrong or incomplete and which incorrect knowledge may be responsible for the error.
- *Interactive problem solving support:* Provide the student with intelligent help on each step of problem solving - from giving a hint to executing the next step for the student.
- *Example-based problem solving:* Help students by suggesting them the most relevant cases (examples previously explained or problems solved by them earlier).
- *Adaptive presentation technology:* Adapt the content of a hypermedia page to the user's goals, knowledge and other information stored in the user model.
- *Adaptive collaboration support:* use system's knowledge about different users (stored in user models) to form a matching collaborating group.
- *Adaptive navigation support technology:* Support student navigation and orientation in hyperspace by changing the appearance of visible links (sort, annotate or partly hide links).

In the following paragraphs, based on the hypermedia nature of the Web and on features of ill-structured domains, we attempt to identify suitable classes of AES.

### 2.1.2 Ill-structured domains

An ill-structured knowledge domain is one in which the following two properties hold ([Spiro96]):

1) Each case or example of knowledge application typically involves the simultaneous interactive involvement of multiple, wide-application conceptual structures (multiple schemata, perspectives, organizational principles, and so on), each of which is individually complex (i.e., the domain involves concept- and case-complexity).
2) The pattern of conceptual incidence and interaction varies substantially across cases nominally of the same type (i.e., the domain involves across-

case irregularity). For instance, in well-structured domains like math or physics, application of the same principles or abstract concepts in similar cases (problems) provides equally similar results. The same does not necessarily hold for an ill-structured knowledge domain such as History, Medicine, and so on.

### 2.1.3 Constructivism and Hypertext – the need for adaptivity

The exact nature of constructivism is one of the broadest and most discussed issues in instructional technology. It is a general feeling that constructivist approaches dominate today's research, especially for systems operating on the World Wide Web. We believe that at least two important features of the Web make it appealing for constructivist learning. The first is its operation as a communication medium that allows activities like peer learning even over large distances and in asynchronous fashion. The second is the fact that the key Web technology is hypertext.

Constructivism, in contrast to behavioristic pedagogy, stresses the importance of generating understanding versus training for performance ([Henze99a]). Generating understanding requires partition of the knowledge domain in declarative, procedural and structural knowledge [Eklund95]. When hypertext structures are based on structures of learning, or cognitive models, within the learner [Eklund95], they promote understanding of structural knowledge, which is the important link between declarative and procedural knowledge. To that end, constructivist instructional theories like Cognitive Flexibility Theory can be employed for effective Hypertext design.

It seems that the non-linear nature and the web-like structure of hypertext render it appropriate for representing complex structural knowledge and thus play an important role in constructivist Computer Based Instruction (CBI). However, use of hypertext for learning has been contested in a series of studies and empirical evaluations. A number of studies emphasize user disorientation problems in hypertext (e.g. [Nielsen90] - perhaps the most cited paper in this field). Compared to more traditional CBI models, two drawbacks of hypermedia can be identified: (1) the deterministic nature of linking (links are unconditional) and (2) the fact that hypertext traversal, especially in WWW applications, is referential (elicited by the user) and not contextual (decided by performance information on the student) ([Kotze98]). It appears that the question of whether the non-linearity of hypermedia is effective for instruction should be replaced by several more specific questions, such as *who, in what and how does non-linearity help*. Individuals vary in skills, preferences, and degree of familiarity with information technology. These differences make individuals more or less likely to take advantage of systems like hypertext, which are based on choice and self-organization ([Rouet92]). It is such problems that curriculum sequencing and adaptive presentation/navigation AES attempt to solve, through the production of individualized instruction with the correct ratio of learner control and user guidance.

### 2.1.4 Ill-structured domains and AES

From the classification of AES presented in Section 2.1.1, it appears that AES classes are grouped into two main areas: problem solving support and adaptation of delivery of instruction. AES that provide problem-solving support are applicable in well-structured domains; AES techniques like building bug libraries and modifying correct examples to match user errors and perceive user misconceptions can be used to support problem solving [Beck99]. However, when the domain is ill structured, problem solving support, as implemented in a series of ITSs, is very difficult and costly to implement. This is more evident if the knowledge domain lacks well-established formalisms (contrary to domains such as math or physics) and teacher-learner interaction is typically carried out in natural language. The problem solving process is difficult to model and perhaps impossible (with today's technologies) to simulate with a machine. It seems very difficult to see a system like ANDES [Conati99], used to coach problem solving, in a complex domain like History. For such reasons, we see curriculum sequencing and its variations (adaptive presentation and adaptive navigation) as the most promising and realistic candidates for implementing successful AES in ill-structured domains.

*Conclusions: Hypertext is a promising means for constructivist learning, but its use leads to problems that may be solved through the deployment of curriculum sequencing, adaptive presentation and adaptive navigation AES. Such hypertext-based systems allow moderation of learner-control vs. learner guidance in navigation and provide for better user orientation. Furthermore, ill-structured domains pose several important problems that are hard to solve for systems that provide problem-solving support and analysis of student solutions.*

## 2.2 The effect of ill-structured domains on the design of AES

***Sub-problem B: How are the basic features of AES affected by an ill-structured domain?***

In order to identify basic features of interest, we first examine an AES reference model and three state-of-the-art AES in Section 2.2.1. The features identified are discussed in section 2.2.2.

### 2.2.1 An AES reference model and three state-of-the-art systems

There are two main approaches for building an AES on the Web. The first is to create a WWW interface on an existing ITS and the second is to construct an Adaptive Educational System specific for the WWW. Since we are concentrating on curriculum sequencing and adaptive presentation and navigation AES, and since very few ITS use adaptive hypermedia (cf. [Brusilovsky98a]), we shall focus on the second approach. Following the

Chapter 5

# PERSONALIZED INTELLIGENT TRAINING ON THE WEB: A MULTI-AGENT APPROACH

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**Abstract** One of the most interesting realm among those ones brought up to success by the development of the Internet is distance learning and training. For this reason, the investigation for adequate architectures and platforms supporting flexible and tailored training solutions is nowadays of great interests in the scientific community. This paper is concerned with the presentation of an original architecture for intelligent distance tutoring which make use of software agents. The way in which the knowledge is represented and stored is discussed together with the ability of our system to manage individual learning paths for different users. The rationale for using Agents is presented and the implementation of the system is discussed.

## 1 INTRODUCTION

The great amount of information available across the Internet brought to the development of new sophisticated information-based technologies; interests in knowledge management, in information retrieval and information filtering are becoming hot topics in several areas for different applications across Internet.

Among the enormous number of such applications, one of the most interesting is the *Distance Learning*. The potential of the Web for providing rich materials and experiences, the possibility and capability to learn more knowledge implied by digital technologies are factors of increasing importance in a world where the amount of information that needs to be learned grows very rapidly and becomes obsolete very quickly. As a matter of fact, the proliferation of Local Area Networks (LANs), and Wide Area Networks (WANs) for telecommunications, information and data applications has brought the enabling technological framework needed to bring network-based multimedia training to full availability of millions of people world-wide.

Interactive training delivered via a computer has been reported to be more effective than traditional classroom lectures, and, moreover, to reduce training time and costs [1], [2]. Exploiting computer delivered training it is possible to increase training effectiveness by increasing student participation, interest and retention of knowledge and reducing attrition level [3]. Fletcher [4] summarized a set of supporting evidences for the benefits of technology based learning systems coming from numerous analyses and specific studies. His conclusions can be summarized as follows.

- Technology can be used to teach: in the absence of any other instruction, technology based learning systems improve student achievement.
- Technology improves instructional effectiveness compared with the "conventional instruction" (lecture, text-based materials, hands-on experience).
- Technology reduces time to reach instructional objective: analyses covering a wide range of content areas (military training, adult education, and higher education) shows an average reduction of the 30% of time if compared with "conventional instruction".
- Technology can be used to teach "soft skills" (soft skills are knowledge and skills associated with social interactions).
- Students enjoy using technology: they are more likely to say they enjoy technology based instructions than conventional mechanisms.

Benefits of computer based training relies on the fact that they exploit a "learner-centered" training paradigm in place of the classical "tutor-centered". Such approach focus on needs, skills and interests of the learner. At the heart of the modern instructional design there is, in fact, the idea that people learn best when engrossed in the topic, motivated to seek out new knowledge and skills because they need them in order to solve the problem at the hand [5].

The purpose of this paper is to present ABITS, an innovative solution for intelligent training over the Internet able to address all these topics. Its features include automatic learners evaluation (through profiling) and intelligent course tailoring based upon user needs and inferred user profiles. ABITS includes and integrates several state-of-the-art technologies: metadata and conceptual graphs for knowledge manipulation, intelligent agents and fuzzy user profiling. ABITS is Web-based: it requires zero cost installation for end-users and can allow them to take training without time and place constraints. Moreover ABITS is content open: it allow easy integration of content from multiple courseware providers and authoring-tools in order to reuse existing didactic material.

The following paragraph is dealt with an overview of ABITS functions while paragraphs 3 and 4 will depict the ABITS internal architecture based on software agents. Finally paragraph 5 will show ABITS in action in a real case.

# 2 WHAT IS ABITS

ABITS stands for "Agent Based Intelligent Tutoring System". It is a Multi-Agent System (MAS) able to extend a traditional Course Management System (CMS) with a set of "intelligent" functions allowing student modeling and automatic curriculum generation. The purpose of such functions is the improvement of the learning effectiveness based upon the adaptation of the didactic material to student skills and preferences.

This chapter is thought as an introduction to these functions. In particular, paragraph 2.2 is dealt with student modeling while paragraph 2.3 describes the ABITS implemented algorithm for curriculum generation. Such functions are depicted in the UML Use Case Diagram of figure 1 where the *Evaluate Curriculum* case is dealt with curriculum generation while the *Evaluate Preferences* and the *Evaluate Cognitive State* cases are related to user modeling.

ABITS functions found their effectiveness on a set of rules for knowledge indexing based on Metadata and Conceptual Graphs. This point is treated in paragraph 2.1.

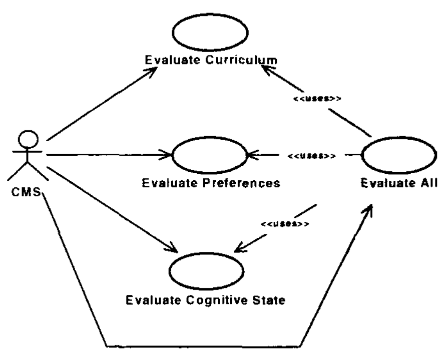


*Figure 1:* ABITS Use Case Diagram

## 2.1 Knowledge indexing

ABITS didactic material is organized in *Learning Objects* and is stored in a Course Material File System. A Learning Object is any entity which can be used, re-used or referenced during technology-supported learning. Learning Objects must be indexed in order to let the system know what each one of them is about and how it can be used during the learning process. Some kind of information about Learning Objects is so required. This is *Metadata*.

"Metadata is information about an object, be it physical or digital and its main goal is to locate in efficient and effective way resources over a system or a computer network" [7]. In the field of learning materials, several organizations such as IEEE, EDUCOM etc focused their attention on the creation of Metadata standards specifying the syntax and the semantics of the so-called *Learning Object Metadata* (LOM).

A LOM standard defines the minimal set of properties needed to allow Learning Objects to be managed, located, and evaluated. They accommodate, moreover, the ability for locally extending the basic properties. ABITS adopts the IEEE LTSC LOM standard [7] to index learning material. Many advantages come in fact from referring to a Learning Object Metadata standard:

- to take advantage of a complete syntax and semantic created by experts of the Learning Technology;
- to enable the automatic importation of extern learning objects that adopt the same Metadata standard;
- to enable the exportation/sale of learning objects to extern systems/clients that adopt the same Metadata standard;

Metadata not only have to provide information about a single Learning Object. They have to provide information about object relations and interdependency too. For this purpose the IEEE LOM standard has a Metadata element called *Idea* that supports *Domain Conceptualizations*. A Conceptualization is an abstract, simplified view of the world that we wish to represent. A *Conceptual Graph* is an explicit specification of a Conceptualization [8]. Conceptual Graphs are graph-like structures composed by *Concepts* and *Conceptual Relations* where every arc links some Conceptual Relation $r$ to some concept $c$.

With the term *Concept* we intend an abstract notion that refers to a particular Conceptual Graph. Conceptual Graphs are used to link Concepts underlying the knowledge domain with several kinds of relations: (prerequisite, sub-concept, general relation, etc). As we will see, Conceptual Graphs are massively used by ABITS functions in conjunction with Metadata fields for Cognitive State modeling and automatic Curriculum Generation.

## 2.2 Student Modeling

ABITS student models are composed by a *Cognitive State* and a set of *Learning Preferences*.

The ***Cognitive State*** contains the knowledge degree, reached by a particular student, of every ABITS tested domain Concept [6]. We represent this information by using an array of *Fuzzy Numbers* (one for each concept). The decision to use Fuzzy Numbers [9] in ABITS Cognitive States arises from the necessity to manage uncertainty in the student evaluation process. In this way, in fact, we can admit different kind of evaluations with different degree of reliability.

As an example, when a student reads an expositive Learning Object (i.e. a lesson) with a given set of Concepts involved, ABITS forecasts a little increase in the knowledge of such Concepts (maintained in the Cognitive State) for this student but with a large degree of uncertainty (read doesn't mean understood). Conversely, when the same student answers correctly to a test related to the same set of Concepts, ABITS can increase again the knowledge degree of such Concepts but with a lower degree of uncertainty (user now is tested). To represent this kind of information we use more and more narrow fuzzy numbers.

Moreover, in order to model the attitude that have humans to forget what they learn, ABITS applies a *Forgetting Function* to Cognitive States. This algorithm, in order to signify that evaluations are more and more unreliable over the time, provides to widen the amplitudes of Conceptual knowledge degrees inside Cognitive States.

Within ***Learning Preferences*** we enclose information about the student perceptive capabilities i.e. to which kind of resources a specified student is shown to be more receptive [6]. To evaluate student preferences ABITS exploits Metadata elements contained in the *Educational* IEEE Metadata Category such as: *Format* (kind of media), *Difficulty*, *Pedagogical Approach*, *Interactivity Level* and *Semantic Density*.

To evaluate student Preferences ABITS exploits this idea: during the learning process there are *Milestones* (points in the student Curriculum) chosen by tutors where the Cognitive State is updated with respect to activities performed by students. After this point, a new evaluation is given for each Concept involved in student performed activities. ABITS can evaluate the pedagogical effectiveness of Learning Object typologies by exploiting the variation between concept evaluations and the Educational Metadata information about visited Learning Objects between couples of subsequent Milestones.

ABITS calculated information about Student Models can be exploited directly by tutors or re-used by ABITS in the Automatic Curriculum Generation procedure.

## 2.3 Automatic Curriculum Generation

Each student can be assigned to one or more different *Courses*. An ABITS Course is composed by a set of *Learning Goals* and by a *Curriculum*.

With ***Learning Goals*** (that are strongly different from Learning Objects) we intend a set of key Concepts necessary to be learnt to successful complete a specific Course. Such Concepts (as all other Concepts) are part of a Domain and are represented inside the Conceptual Graph of such Domain.

With ***Curriculum*** we intend, instead, an ordered list of Learning Objects that can be used to provide to a specific student all necessary knowledge to complete a specific Course. While Learning Goals indicate what (which Concepts) a student has to learn, Curriculum specify how these Concepts has