A Digital Market Place for Education

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**Abstract -- We describe a web-based Educational MarketPlace that matches student requests 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 dynamic 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 paper 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.**

I. PROBLEM STATEMENT

The Internet contains thousands of instructional systems and objects that might be searched, tailored and presented to a student in response to a query. However, people can not comprehend nor fully exploit the huge amount of available on-line knowledge. These materials need to be tailored by agents that model the student's knowledge and by machine learning techniques that assemble resources into customized end-products.

The problems that prevent people from obtaining maximal benefit from the Internet are characterized by the great diversity in prerequisites, quality, approach, cost and availability of resources. The huge amount of available on-line knowledge surpasses the ability of people to locate, evaluate or manipulate. In education, like other economic sectors, thousands of resources exist and the environment is in constant flux, see Table 1. Currently, 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. 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.

We describe an Educational MarketPlace, or a system of tools, which match student queries to available and appropriate educational resources. Development of this MarketPlace requires addressing technical issues such as: 1) resource acquisition and data mining techniques to facilitate access to large-scale educational repositories; 2) resource acquisition and data mining techniques to facilitate access to large-scale educational repositories; and 3) digital repository testbeds to evaluate agent behavior. Societal research issues include understanding web-based educational interactions, individual learning processes and organizational dynamic in the distributed, digital instructional realm.

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

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

Table 1: Existing Instructional Repositories

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might receive only spoken software. The educational network should use student modeling and machine learning techniques to assemble and tailor resources. The student should access classes of objects, distributed across heterogeneous repositories and customized by mediating software that compensates for site-by-site variations.

Many commercial Internet MarketPlaces now exist; however, the Educational MarketPlace will be different, requiring, for instance, independent scoring of instructional material, checking the certification and reputation of objects and authorizing contract fulfillment. It will provide students with a vast array of learning opportunities, support entry of new competitors and learning paradigms into the education enterprise and address the rising educational need and cost. Teaching systems on the web could become the primary source for education, helping to dissolve the cottage industry of education in which a teacher handcrafts materials fixed by space and time. The current education monopoly might be transformed into an open learning environment in which the learner has choices in the marketplace. This paper discusses the transformation and suggests technological and social barriers to be addressed

II. EDUCATION AS E-COMMERCE

Universities enjoy a monopoly over education. Currently higher education is maintained as a cottage industry, with faulty handcrafting courses from scratch and delivering made-to-order programs to a specific 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 from 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 forms of learning will become "commodities" 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 the producer push (instructor offerings).

Most faculty are not adept at "packaging" content for mass audiences, even though some write textbooks. Most marketing and distribution is done by outside publishers. Faculty are skilled at creating content for their lecture-based programs. In the Internet, the university may need to outsource production and distribution of its 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 view point 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].

III. COMPONENTS OF THE SOLUTION

Many technical and social barriers need to be addressed before education becomes an open global learning market place. 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, market place 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, creation of student and knowledge models that persist for a lifetime and improve over time and the maintenance of privacy.

We are building an Education Network, or ENET, containing classes of agents representing students and resources, see Table 2. These components are described further in Section IV. Information retrieval techniques are being integrated into a digital marketplace that represents and delivers instructional material, manages the tangled

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 (CCA)	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
Market Place	Enable the assembly of resources.	Manage large dynamic open systems; develop market institutions; help anticipate, avoid and detect non-compliant resources.

Table 2. Components of ENET

Web of resources and students and respects the privacy of students. Authors of educational resources will be encouraged to contact ENET to register their resources into the marketplace, but ENET will also actively search for and incorporate resources without any specific action by developers.

ENET 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. It 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."*

IV. Proposed Solution

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 market place is different requiring 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 market place can only support certified resources. To allow student agents to confidently contract with new resources, the instructional market place 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 money can change hands in an open system such as education, an assumption of honesty is not safe to make. The instructional marketplace will provide means for keeping both student and pedagogical agents honest. As each instructional event occurs, e.g., the generation of a new screen, the pedagogical agent can pass notice through the regulatory agency of the instructional marketplace and to the student agent to register the event.

ENET will locate and coordinate online educational resources to satisfy the user's specific educational goal. Conceptually, there are three required functions: *location, coordination* and *decomposition* of resources. 1) We envision using search engines to acquire new resources such as movies, sound files and raw text documents, e.g., technical reports and journal articles. 2) ENET will coordinate disparate educational resources into a lesson plan adapted for each user without having domain-specific knowledge. 3) Educational resources will be automatically decomposed into sub-topics, to permit fine-grained interleaving of resources into the end-product.

V. Potential Advantages of the Suggested Solution

This project has both technical and societal research components. Technical research includes: 1) development of a virtual marketplace to support negotiation, contract execution and verification of instructional resources;
2) implementation of resource acquisition and data mining techniques to facilitate access to large-scale educational repositories; and 3) development of a digital library/repository testbed to demonstrate integrity, reliability and accuracy of the machine learning, information retrieval and agent technology. We will demonstrate, for example, that agents will learn to coordinate specialized learning resources to solve difficult learning problems.

Societal research includes understanding the nature of web-based educational interactions, individual learning processes and organizational dynamic in the distributed, digital instructional realm. This research includes: 1) the adequacy of the assembly, negotiation and usability of resources, 2) search and retrieval performance and behavior, 3) the effect on users and 4) fundamental changes in classroom activities. These problems will be studied from the viewpoint of the individual, class, institution and community.

The potential impact of this work is enormous, e.g., providing students with a vast array of learning opportunities, supporting entry of new competitors and learning paradigms into the education enterprise and addressing rising educational needs and cost. The market place will help eliminate space and time constraints, accelerating anyplace and anytime education and maximizing the benefits of new information technologies. The law of supply and demand will no longer be prevented from influencing education.

VI. Assumptions

Given the Instructional Market Place, a user will log onto her personal assistant to solve a vibration problem in an advanced engineering course. The personal assistant will:

1. Break the activity into manageable subunits;
2. Locate teaching components appropriate for different units;
3. Identify pre-and post-conditions for each component;
4. Construct an instructional plan and tutoring strategy by assigning optimal resources to each subgoal, given the user's background, goals, time, and monetary considerations;
5. Make contracts with agents for the teaching resources by planning resource assignment, requesting resources availability, managing bids and proposing contracts and schedules;
6. Monitor ongoing learning, intervening when necessary and collecting statistics about the effectiveness of resources.

The marketplace will provide mechanisms to support both the creation and fulfillment of agent contracts in a large heterogeneous, dynamic environment. Key features of the marketplace will be *quality of service*, *resource appraisal, centralized ontology* and *negotiation protocols*.
1) A guarantee of the base level of *quality of service* will be refined to gain user trust and acceptance; this kind of quality assurance is valuable in any marketplace.
2) Agents will *appraise resources* and provide public ratings. 3) A *centralized ontology* will synchronize the assembly of educational resources from different authors into a coherent lesson for the student. The ontology will specify a one-to-one correspondence of concepts to terms, simplifying and increasing the accuracy of negotiation for

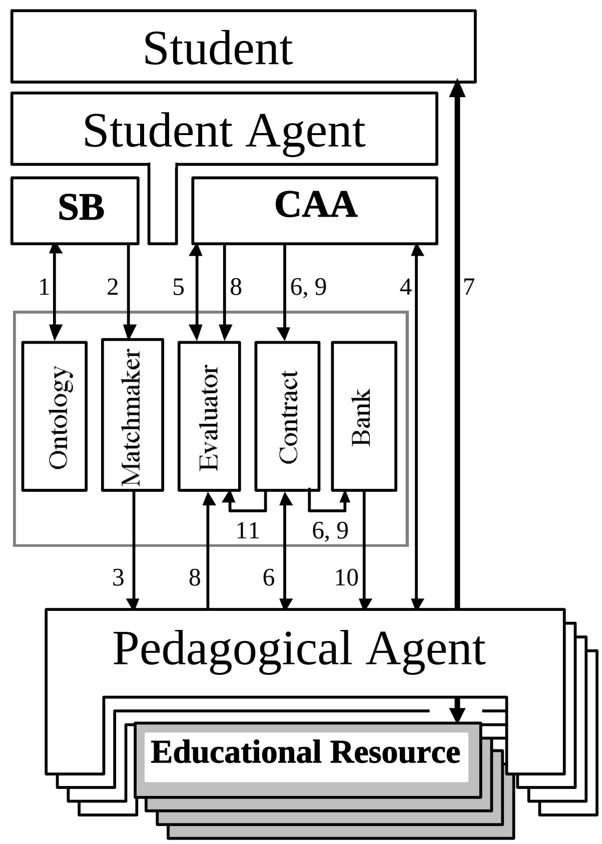

Figure 1: Basic ENET Architecture
Key : 1. SA forms goals using ontology agent; 2. SA sends goals to matchmaker; 3. Marketplace sends goals to selected PAs; 4. PAs return bids and negotiate contracts with CAA; 5. CAA uses evaluator in selection;
6. Contract is registered in the Marketplace; 7. Student and educational resource interact; CAA and PA inform evaluator of progress; 9. CAA informs contract agent of completion and payment type; 10. Bank pays PA;
11. Evaluator is informed of success.

resources to provide each topical segment of a lesson plan. 4) *Negotiation protocols* will be established and followed by every agent contracting in the marketplace in order to receive the full support of the marketplace.

For example, some resource may require as a prerequisite the student's enrollment in a specific course. If this course is unavailable, then the entire lesson plan may be invalidated. With a leveled commitment contract protocol, agents in ENET will be able to negotiate in good faith in the face of such contingencies [Sandholm, 1999; Lesser et al, 1998].

A. Student Agents

Student Agents (SA) will serve students and manage negotiation and planning, see Figures 1 & 2. If a student needs refined or additional material, the *SA* will use student records to further customize instruction. The *SA* is integrated with a *Searchbot Agent (SB)* and a *Course Assembly Agent (CAA)* which may be provided by domain-specific agents found in the market place and coupled with the Student Agent.

Searchbot Agents (SB). Searchbots will help Student Agents search for instructional service provider agents, using a model of the student's background, activities and individual competencies [Beck et al.,1997; Eliot & Woolf, 1995]. Student data will be updated automatically through user modeling and machine learning techniques. SBs will find candidate instructional agents by sending out RFBs and collecting bids for a prospective student, with the help of matchmaker services. We will focus on developing the searchbot student model while simply incorporating the sophisticated information retrieval methods developed by other researchers.

Course Assembly Agents (CAA). These agents will assemble course plans using resources provided by instructional agents. This highly innovative research will be one of the core intellectual contributions of the research. Instructional resources will be modeled as plan operators with pre- and post-conditions describing the students' expertise before and after the course; initially most resources will only have incomplete and partially accurate models of their pre- and post-conditions. Course assembly agents will use innovative evaluation mechanisms to reason with and improve fuzzy plan operators through learning. Another challenge is working in a domain where the types and properties (quality, availability and cost) of the available plan operators vary dynamically (services will appear and disappear, become committed and later available again, change in price dynamically as supply and demand is reflected in auction prices). Finally the course assembly agents will need to reason about the varying reliability of these resources, and how this can be traded off against resource cost, quality and availability.

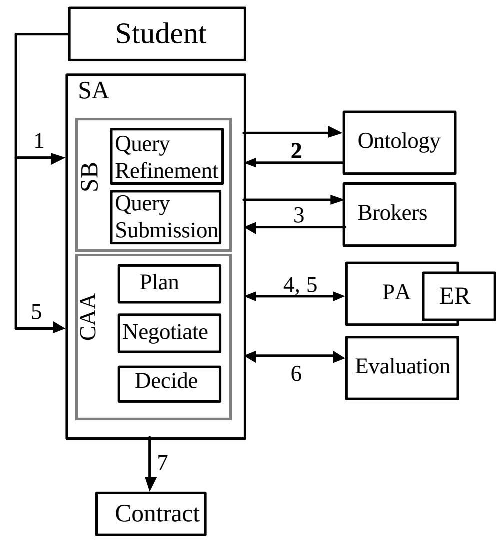

Figure 2. Functions of a Student Agent

1. Initial query submitted; 2. Formalization of terms; 3. Submission of formal query; 4. Brokers or PAs suggest breakdowns; 5. PAs submit bids and negotiate with student.

B. Pedagogical Agents

Pedagogical Agents (PA) will be linked to instructional resources, track teaching methods and effectiveness, organize resources and negotiate with *Student Agents* to customize instruction for an individual student. Pedagogical Agents include *Resource Agents* that exploit existing Internet resources to provide instruction.

Resource Agents (RA) are specialized pedagogical agents that 'wrap' Internet-based instructional resources such as web pages, online databases and human tutors. Easily customizable 'shells' will be developed to accommodate existing on-line teaching resources. The resource agents will interact with the educational market place as pedagogical agents and convert knowledge in the form of existing on-line resources to provide instruction.

Resource Classifiers will automatically deduce or refine pre- and post- condition models for pedagogical agents, providing the critical information needed to integrate resources into a consistent ontology so they can be combined into useful sequences by the course assembly agents. These classifiers will learn better resource models over time based on performance feedback from the evaluation agents. This is the second key intellectual contribution of the work. Current technologies have not attempted to achieve this capability, limiting themselves to rudimentary topic models based, for example, on word frequency statistics.

C. *Market Institutions*

Market Institutions will enable the assembly of complex instructional plans. This is the third key intellectual contribution of the project. Mechanisms will provide for contract negotiation, monitoring, contract compliance and accreditation [Klein, 1998a 1998b; Dellarocas & Klein, 1999a 1999b]. User modeling, planning and machine learning will provide robust performance despite changing availability of resources, modifications in the network and variable user needs. Agents will communicate in a peer-to-peer fashion to allow specialized learning resources to solve specific aspects of larger problems [Klein, 1993].

ENET requires capabilities that will be more sophisticated than those of existing marketplaces [Klein, 1993]. These include: 1) *coordination mechanisms* that support planning, negotiation, contracting and delivery of instruction; 2) *appraisal, certification and verification* of the capabilities of resources; and 3) *exception handling* that detects and resolves unexpected problematic situations.

VII. Expanded Overview and Example

The architecture has two phases of interaction between the Student and Pedagogical Agents and the Marketplace: a scheduling phase and an instructional phase, see Figure 1. We now provide an extended example to illustrate how the different elements of the architecture will work together to produce a course of instruction to meet such a moderately complex educational request.

This example shows how the system operates during a single student interaction. Some functions of the agents, particularly the Resource Classifier and Resource Agents, involve manipulation of statistical results of many student interactions and are not illustrated in this example.

Scheduling Phase. In this example, the student enters a query requesting a course in biomedical engineering (BME). The SA keeps track of its student, maintaining a complex student model that includes the student's transcript, prior knowledge, job description and relevant personal data. with the ontology maintained by ENET. The SA posts a query to the marketplace "Seeking a course covering BME at a college level."

The marketplace receives the query, and must ensure that the student agent has available an appropriate Course Assembly Agent (CAA), see Figures 1 & 2. If required, the SA uses the marketplace to locate a suitable CAA and negotiates the required services. The CAA will provide domain-specific planning capabilities to develop a coherent educational plan.

Next the CAA resends the query to the marketplace. Pedagogical Agents (PAs) represent educational resources, on a continuum of complexity ranging from full-fledged intelligent tutoring systems, to static resources such as online research papers and multimedia objects, to topic decomposition services. The marketplace sends the request for bids through its yellow pages module, winnowing down the multitudes of PAs to a relative few judged most relevant to the desired educational goals.

Suppose that in our example there are no intelligent tutoring systems or even explicit topic breakdowns covering BME. Instead, the yellow pages service will return a set of decomposition services that can potentially decipher the query topic of Biomedical Engineering and break it into subtopics for which instructional resources do exist.

Through negotiation the SA develops an appropriate decomposition, which is used to assemble Internet resources to provide instruction in BME based upon calculus, physics, statistics, chemistry, biology, and medical courses. Potential sources for this breakdown information include research papers, course syllabi and BME degree requirements at University web pages, and so on.

The CAA will interact with the SA to discover which topics in the decomposition the student already has learned. In this case, the student has already covered college level calculus, chemistry, and physics, but is lacking biology, statistics and medical courses. After updating the decomposition to reflect the student's background, the CAA will form a rudimentary plan and attempt to bind topic leafs of the plan to resources using the instructional marketplace.

The CAA will use what information is available about each of the resources from the evaluation mechanism and from the resources themselves to decide which to use and how to order them. Some will be prerequisites for others; some will have subject matter overlapping with others, suggesting that more efficient choices may be available; some will have much higher quality than others. Ultimately, a lesson plan will be generated for student approval, subject to which the SA will finalize all contracts.

Instructional Phase. When the contracts are made, the system enters the instructional phase. During instruction, the student accesses the educational resources; the agents observe the interaction, but do not contribute to it. The role of the agents during the instructional phase is to ensure that the services are rendered smoothly. The role of the marketplace is to mediate disputes between the agents—was the service contracted for rendered—and to monitor the performance of the educational resource/pedagogical agent combinations.

VIII. Impact of This Work

Work in this area ensures that providers entering the Educational MarketPlace will introduce resources that teach effectively and contain intellectual merit. Ineffective and non-useful resources will be rated poorly and cease to be selected or earn revenue. Schools and colleges in the U.S.A. have been caught in a financial vise since in the late 1970s [Dunderstadt, 1997]. While public support for education has flattened or declined, enrollment has grown and costs have risen. The educational needs of society have increased and diversified, as more disadvantaged and non-traditional students enter the educational system. Existing institution will change as new types of institutions are formed to satisfy the need.

People will use the instructional market place to upgrade their job skills, eliminate educational deficiencies and prepare for work. Such a market place also impacts publishers, universities, for-profit companies and individual authors who now maintain physical repositories of instructional resources. By guaranteeing intellectual property rights and revenue, publishers and developers will be encouraged to create web-based resources, making their work more widely available. This work will also assist academic libraries, which have already been changed by the move towards a digital, distributed infrastructure, fueled in part by The Digital Library [Bishop et al., 1995].

This work also addresses fundamental research questions related to large scale markets, agents, information retrieval and (dis)assembly of resources for students. The design, implementation and testing of this market and agents raise several fundamental scientific problems. Technical innovations include:

- (Representation) Providing a set of simple standardized pedagogical agent shells for wrapping common types of web instructional resources (e.g. web pages), ideally fully automatically.
- Implementing negotiating mechanisms for agents to best represent the interests of the instructional resource owners.
- Learning more accurate models of the instructional resources.
- (Resource Classifiers) Finding pedagogical pre- and post- conditions; automatically classify instructional resources that are interactive applications (e.g. on-line tutors) rather than simply collections of text (or html) with a standardized interface (e.g. FTP, HTTP, SQL).
- (Agent technology) Developing an appropriate interface to support effective negotiation over achievable quality, cost and duration
- Developing the ability to disassemble and reassemble instructional resources
- (Markets) Handling 'non-compliant agent' exceptions in instructional marketplaces; Create electronic marketplaces with exception handling. that offers great assurances to buyers and is reasonably priced for sellers.

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