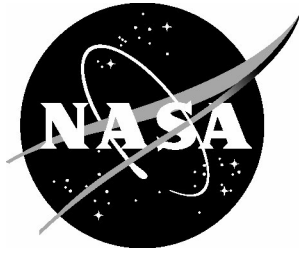# Advanced Learning Technologies and Learning Networks and Their Impact on Future Aerospace Workforce

Compiled by
Ahmed K. Noor
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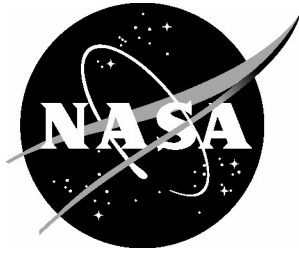
Advanced Learning Technologies and Learning Networks and Their Impact on Future Aerospace Workforce

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PREFACE

This document contains the proceedings of the training workshop on Advanced Learning Technologies and Learning Networks and their impact on Future Aerospace Workforce. The workshop was held at the Peninsula Workforce Development Center, Hampton, Virginia, April 2 – 3, 2003. The workshop was jointly sponsored by Old Dominion University and NASA. Workshop attendees came from NASA, other government agencies, industry, and universities. The objectives of the workshop were to: 1) provide broad overviews of the diverse activities related to advanced learning technologies and learning environments, and 2) identify future directions for research that have high potential for aerospace workforce development. Eighteen half-hour overview-type presentations were made at the workshop.

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Perspectives on
Advanced Learning Technologies and Learning Networks and Future Aerospace Workforce Environments

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INTRODUCTION

The engineering profession resonates with rhetoric about the needs for radical restructuring of engineering education and training, and the opportunities for enhancing learning through the use of new technologies. But while the volume of the standard rhetoric accurately reflects an urgently growing sense that learning in the new millennium should be radically different, its content seldom reflects strategies and detailed, practical plans for effecting that change. Current research and development activities in learning technologies are characterized by being, a) fragmented and disparate, and b) mostly concentrated on near-term product development.

Attempts have been made to remedy these problems - for example, NSF sponsored Engineering Education Coalitions, and the Learning Federation is developing a research agenda for learning technologies designed to have the greatest impact on post-secondary and life-long learning in science and technology. However, to date, they have not made a significant impact on engineering workforce training.

To set the stage for succeeding presentations, an overview of the advanced learning technologies is given in this presentation along with a brief description of their impact on future aerospace workforce development. The presentation is divided into five parts (see Figure 1). In the first part, a brief historical account of the evolution of learning technologies is given. The second part describes the current learning activities. The third part describes some of the future aerospace systems, as examples of high-tech engineering systems, and lists their enabling technologies. The fourth part focuses on future aerospace research, learning and design environments. The fifth part lists the objectives of the workshop and some of the sources of information on learning technologies and learning networks.
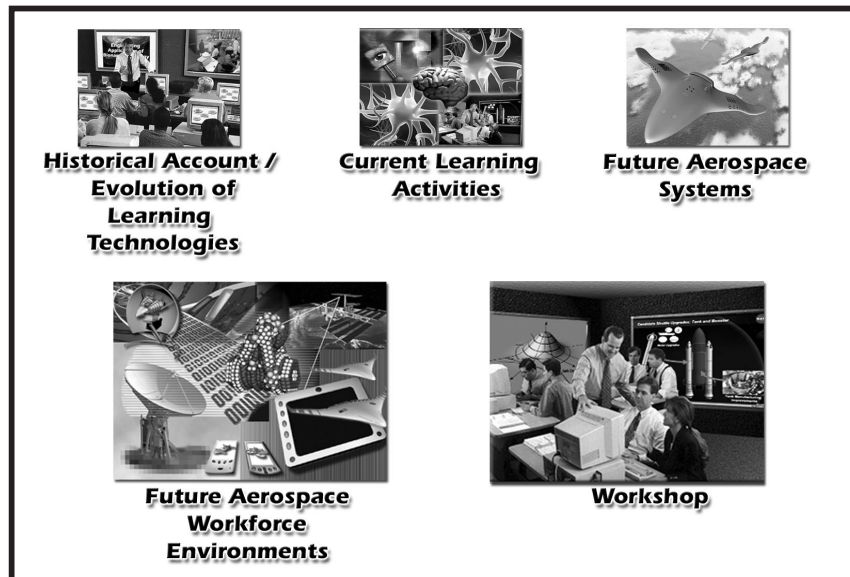

Figure 1

EVOLUTION OF LEARNING TECHNOLOGIES

Computer-based learning technology dates back to the 1960s (see Figure 2). Passive computer-based instruction systems were built in the 1960s and 1970s. Later developments in that period included learner modeling and more elaborate computer-learner interfaces.

The addition of expert systems to computer-based instruction resulted in the Intelligent Tutoring Systems (ITS) of the 1970s and 1980s. These systems had explicit models of tutoring and domain knowledge, and were more flexible in their response than computer-based instruction. The advent of intelligent agents, which enabled the learner to manipulate cognitive artifacts from several perspectives or viewpoints, led to the Interactive Learning (IL) systems of the 1990s. In the late 1990s, a move towards Collaborative Distributed Learning (CDL), with distributed resources, occurred. Current trend is towards using Learning Networks (LN), for enhancing the effectiveness, access and affordability of learning. In learning networks extensive use is made of intelligent agents, learning is guided by cognitive systems, and the learner is an active and reflective participant in the learning process.
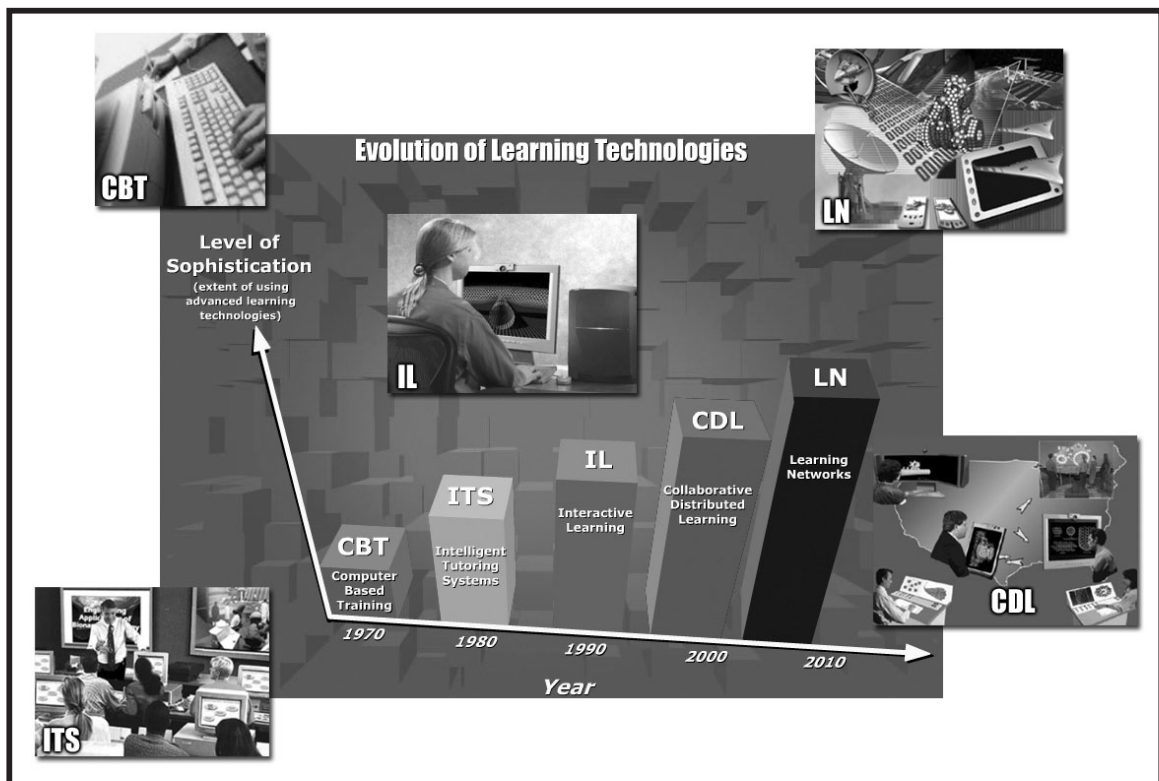
Figure 2

EDUCATION, TRAINING AND LEARNING

There has long been a philosophical gap between education and training. The goal of education was to impart high-level cognitive skills that would underpin lifelong learning. The goal of training was to bring performance up to a level that would let people successfully achieve tasks. Recently, however, training began to emphasize the skills involved in lifelong learning, as evidenced by continual-growth workshops and online training facilities on the Internet. In a sense, both education and training objectives fit in the larger classification of learning objectives (Figure 3).
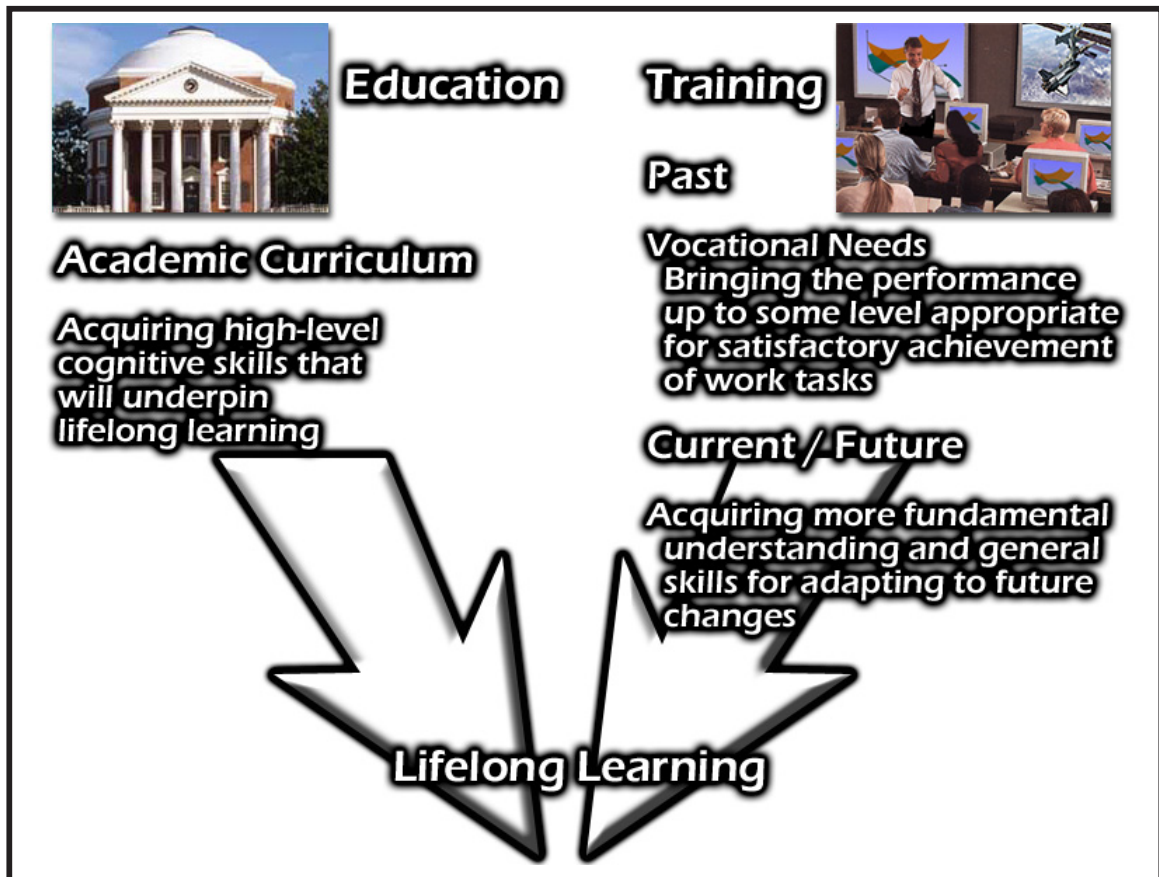
Figure 3

LEARNING OBJECTIVES, INSTRUCTIONAL MODELS
AND TECHNOLOGIES

The desired outcome of learning can range from information transfer to skill and knowledge acquisition to the more ambitious goal of development of critical thinking and creativity skills. The instructional model and method used for accomplishing these goals vary from instructor-centered, learner-centered to learning-team centered. In the learner-centered model, the learner is at the center of the learning process, and calls on many information sources. Learning-team center models include virtual classrooms and web-based distance learning models. The technologies employed in the three models are distribution, interactive and collaborative technologies, respectively (see Figure 4).
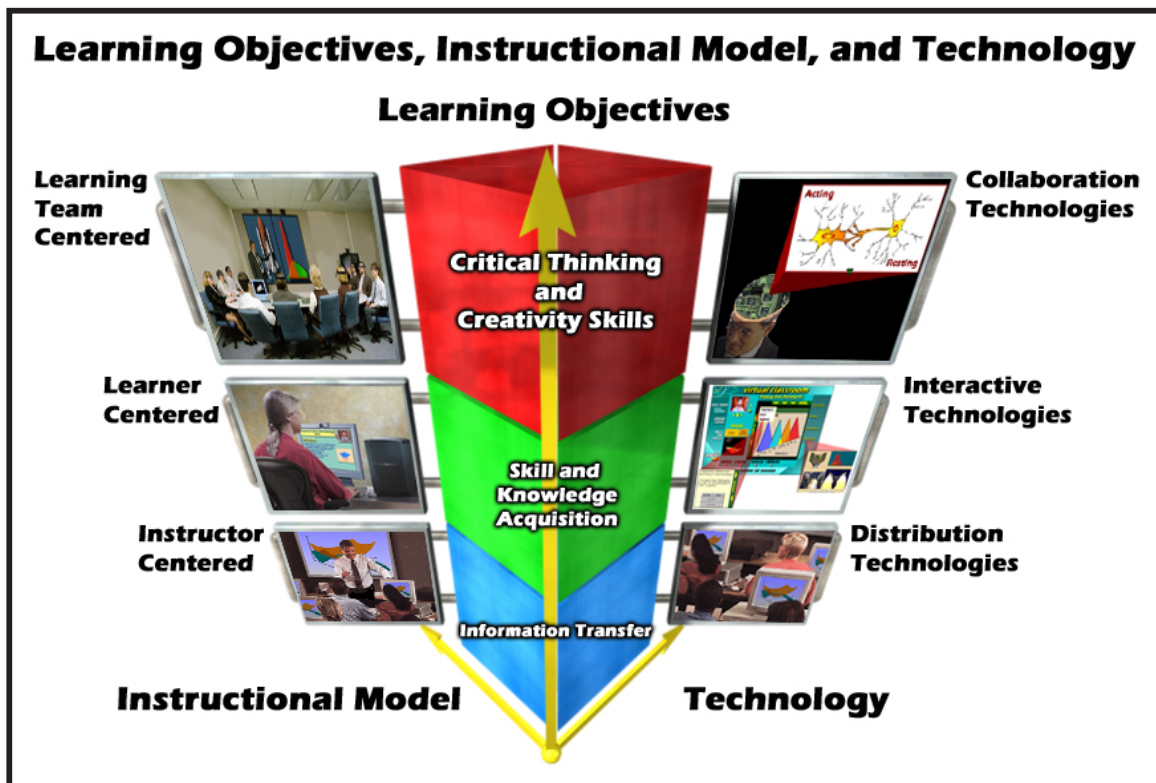
Figure 4

LEARNING NETWORKS

The convergence of computing, communication and information technologies is providing opportunities for creating effective environments for life-long learning through expanding the concept of a university which is, typically limited to a campus, to that of a learning network (Figure 5). In such a network, the classrooms are augmented by e-learning facilities (e.g., virtual classrooms); the libraries are expanded into intelligent knowledge repositories (with digital libraries and intelligent search and information visualization capabilities); the physical test and experimental facilities are augmented with access to more elaborate facilities at government labs, along with computer simulation of these facilities; and Immersive telepresence technology is used to provide interaction with geographically dispersed instructors and learners at other locations.

Figure 5

ACTIVITIES OF LEARNING NETWORKS

The learning networks can significantly enhance the effectiveness of engineering education, by changing the way three of the major functions of a university are carried out, namely, development of content for courses, packaging courses into curricula and programs, and delivery of these programs to learners (Figure 6).

Each course is divided into self-contained learning modules, and a consortium is established for generating the best content for each of the learning modules. Advanced instructional technology; modeling, simulation and visualization facilities and authoring tools are used in the development of the modules.

The learning modules are then packaged into disciplinary and interdisciplinary courses and training programs to satisfy the needs of diverse groups.

The packaged modules are presented to individuals as well as groups of learners. Collaboration and interaction is made available at many levels, both synchronously and asynchronously.
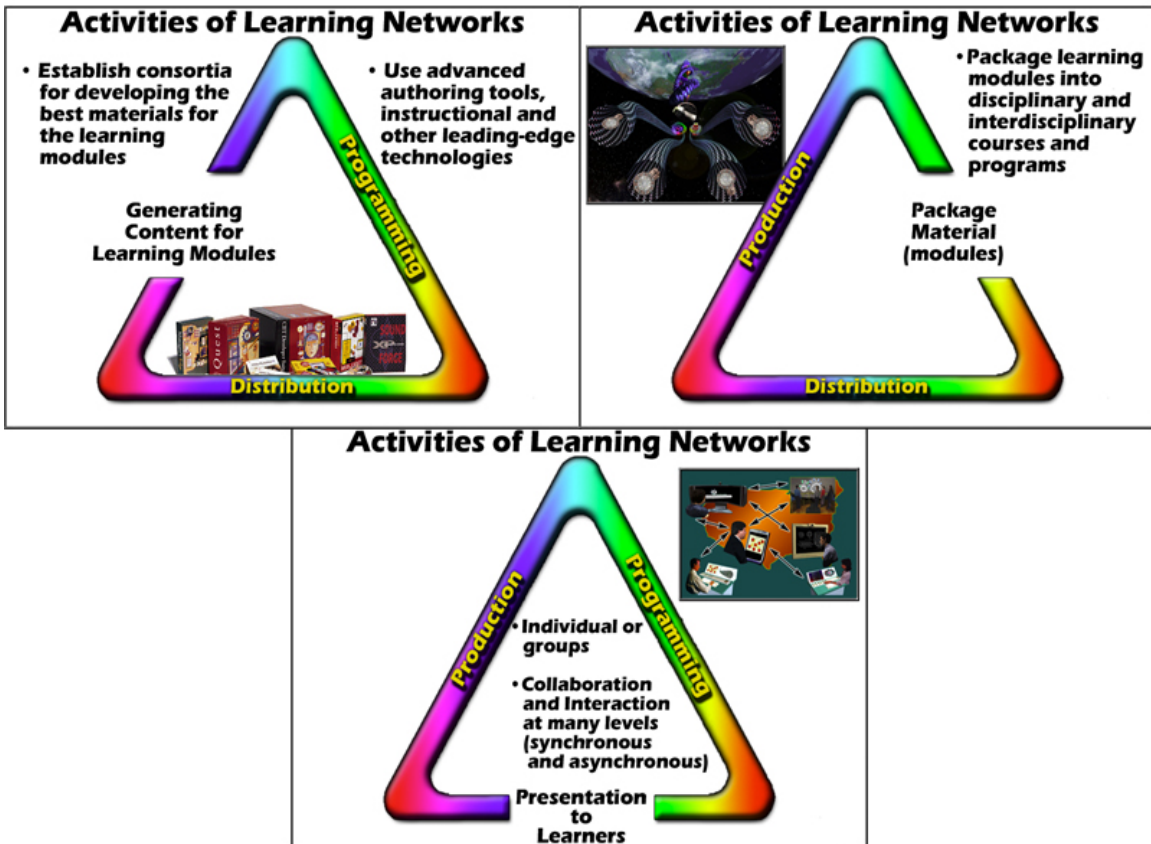
Figure 6

ADVANCED LEARNING ENVIRONMENTS

In order to meet the life-long learning demands of the future and broaden the awareness among the researchers and engineers in high-tech areas, three categories of learning environments are needed; namely, expert-led group learning environment; self-paced individual learning environment; and collaborative learning environment (Figure 7). The three environments, in combination, can reduce the time and cost of learning, as well as sustain and increase worker competencies in high tech organizations.

The human instructors in these environments will serve many roles, including inspiring, motivating, observing, evaluating, and steering the learners, both individually and in distributed teams.

Figure 7

EXPERT-LED LEARNING ENVIRONMENT

The human instructors in expert-led distributed learning in a virtual environment serve as coaches, guides, facilitators, and course managers. Their presentations focus on a broad overview of the topic and its diverse applications (Figure 8), and end with more penetrating, what-if questions that can enhance the critical thinking and creativity of the learners. Elaborate visualization and multimedia facilities are used in the presentations. Routine instructional and training tasks are relegated to the self-paced individual learning environment.
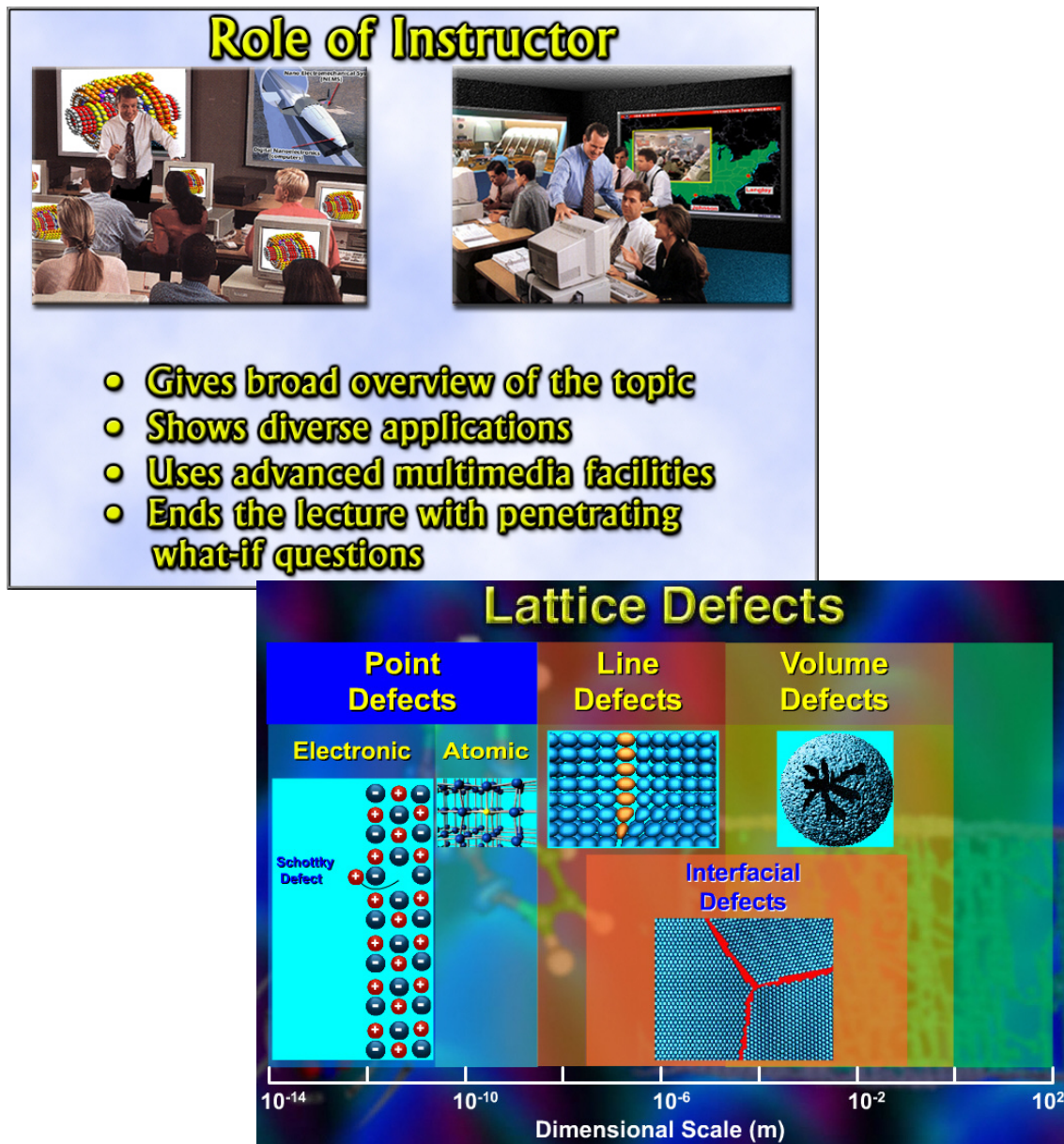
Figure 8

SELF-PACED LEARNING ENVIRONMENT

The individual learning environment engages the learner and provides a high degree of tailored interactivity. It can be used for self-paced instruction of routine material not covered in the lecture. Using virtual instructors assigned by the human instructors can enhance such instruction. It can be used to study the physical phenomena occurring at different length scales using advanced visualization, multimedia and multisensory immersive facilities. The individual learning environment can serve to carry out numerical and virtual experiments - computer simulation of physical experiments (Figure 9).

Figure 9

SELF-PACED LEARNING ENVIRONMENT
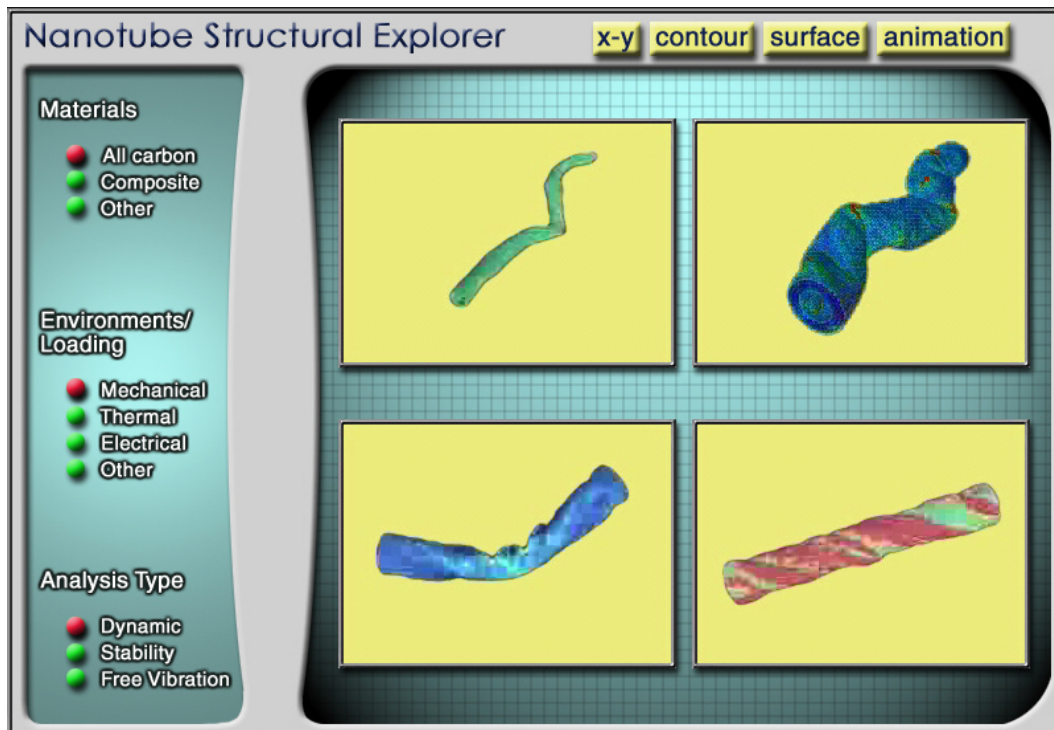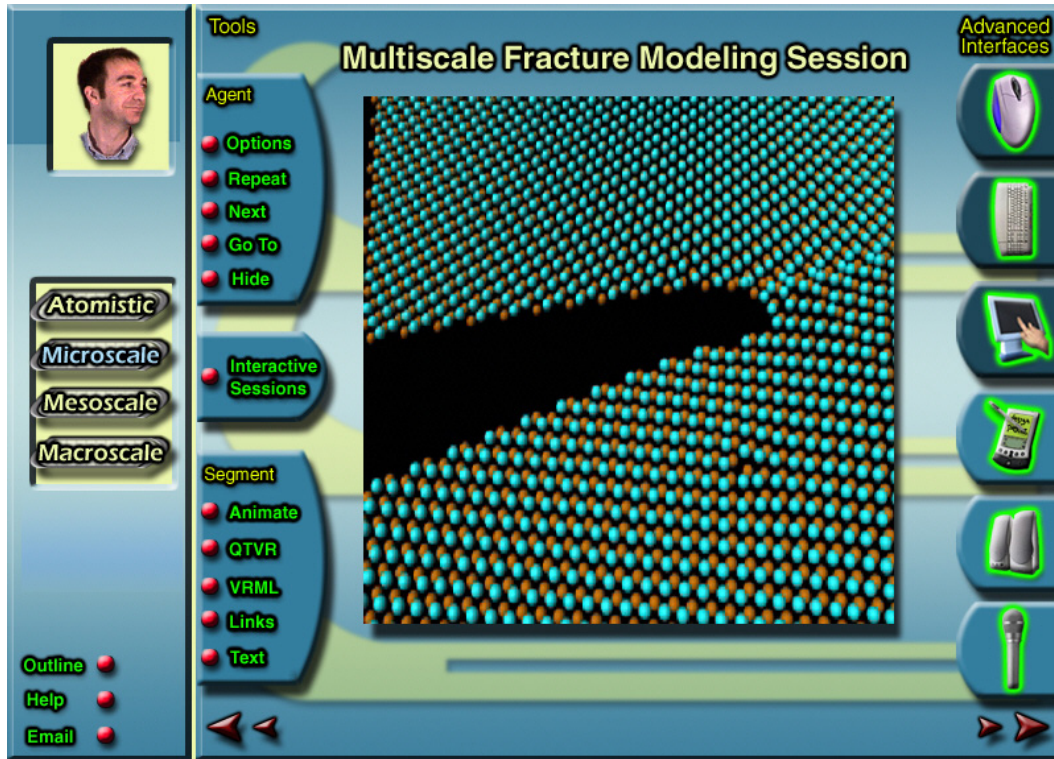
Figure 9 (continued)

COLLABORATIVE / DISTRIBUTED LEARNING ENVIRONMENT

Collaborative learning environments teach teamwork and group problem solving. Instructors and learners can be geographically dispersed. Eventually, they can be brought together through immersive telepresence facilities to share their experiences in highly heterogeneous environments involving different computing platforms, software, and other facilities, and they will be able to work together to design complex engineering systems beyond what is traditionally done in academic settings. Because participants can be virtually co-located without leaving their industry and government laboratories, collaborative learning environments can enable the formation of learning networks linking universities, industry and government labs. The ultimate goal of these learning facilities is to create an intellectual environment where academic and experiential learning are effectively and efficiently co-mingled. In such an environment, academic rigor is learned in concert with professional job performance, and academic complexities are addressed within the industrial concern (Figure 10).
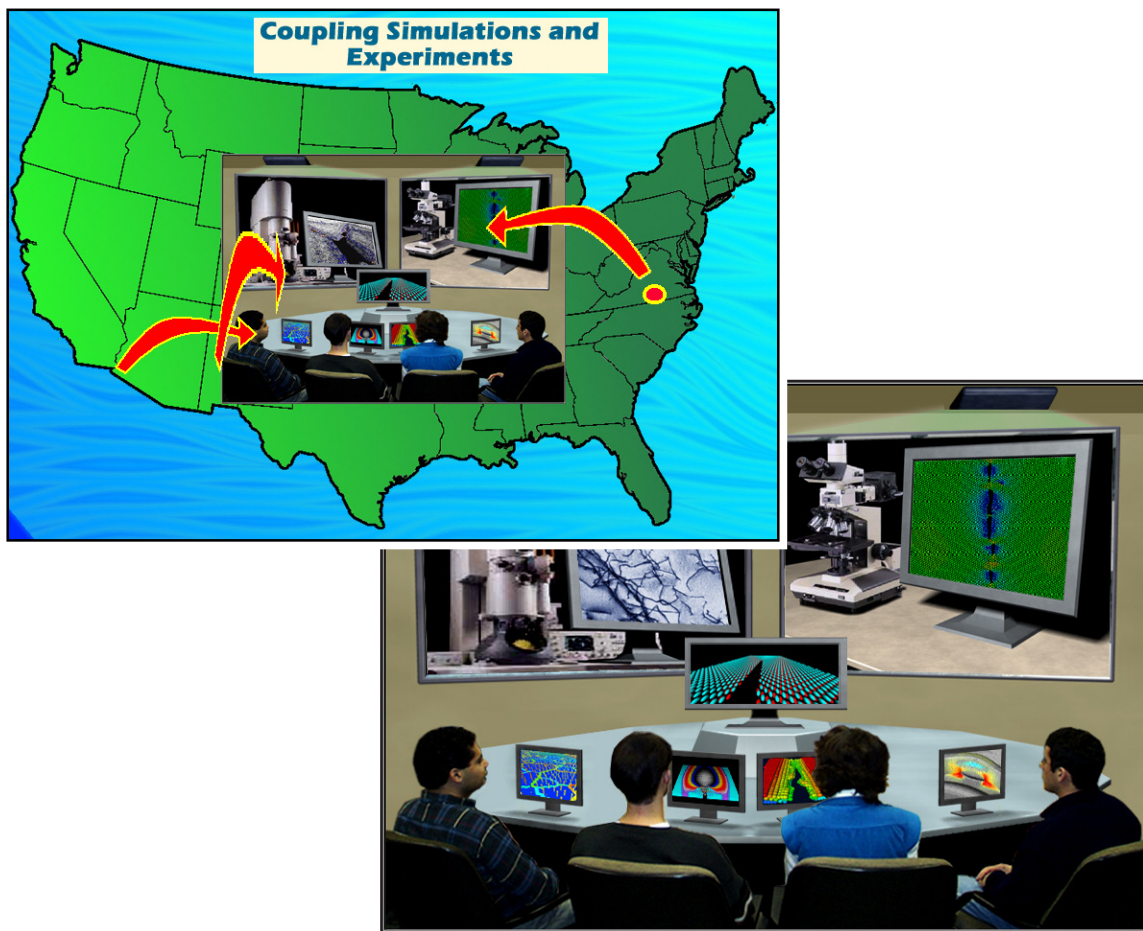
Figure 10

COLLABORATIVE / DISTRIBUTED LEARNING ENVIRONMENT
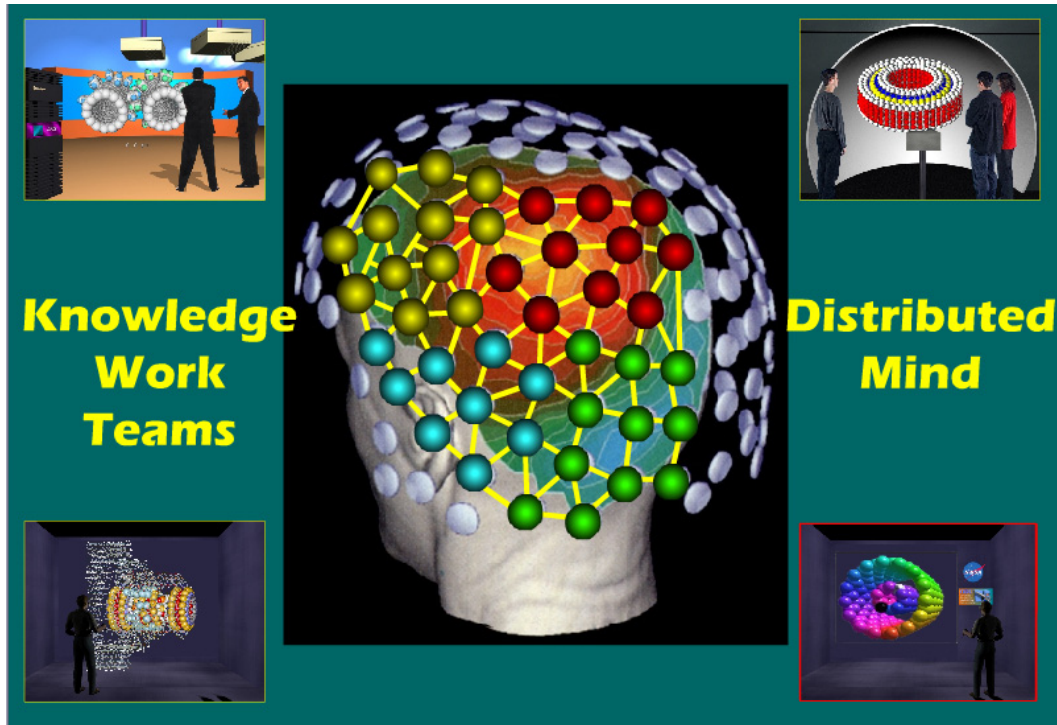
Figure 10 (continued)

SPECTRUM OF LEARNING ACTIVITIES

The various learning activities can be grouped into three categories: learning science; learning technologies, infrastructure and tools and; learning systems (Figure 11). The first category include human cognition/cognitive learning and thinking processes; learning strategies, mechanisms and approaches; models of instructor/learner interaction; knowledge representation and; evaluation, assessment and measurement issues in learning, and monitoring of learner behavior. The second category cover advanced simulation and interrogative visualization facilities; multimodal and adaptive interfaces; tools that support active engagement in tasks, collaborative and reflective processes; intelligent and mobile agents to provide help, motivation and move scenarios forward and; knowledge management, assessment and evaluation tools. The technologies and facilities can be integrated into the three learning environments: expert managed, self-paced and collaborative. The third category include e-learning systems and learning networks.
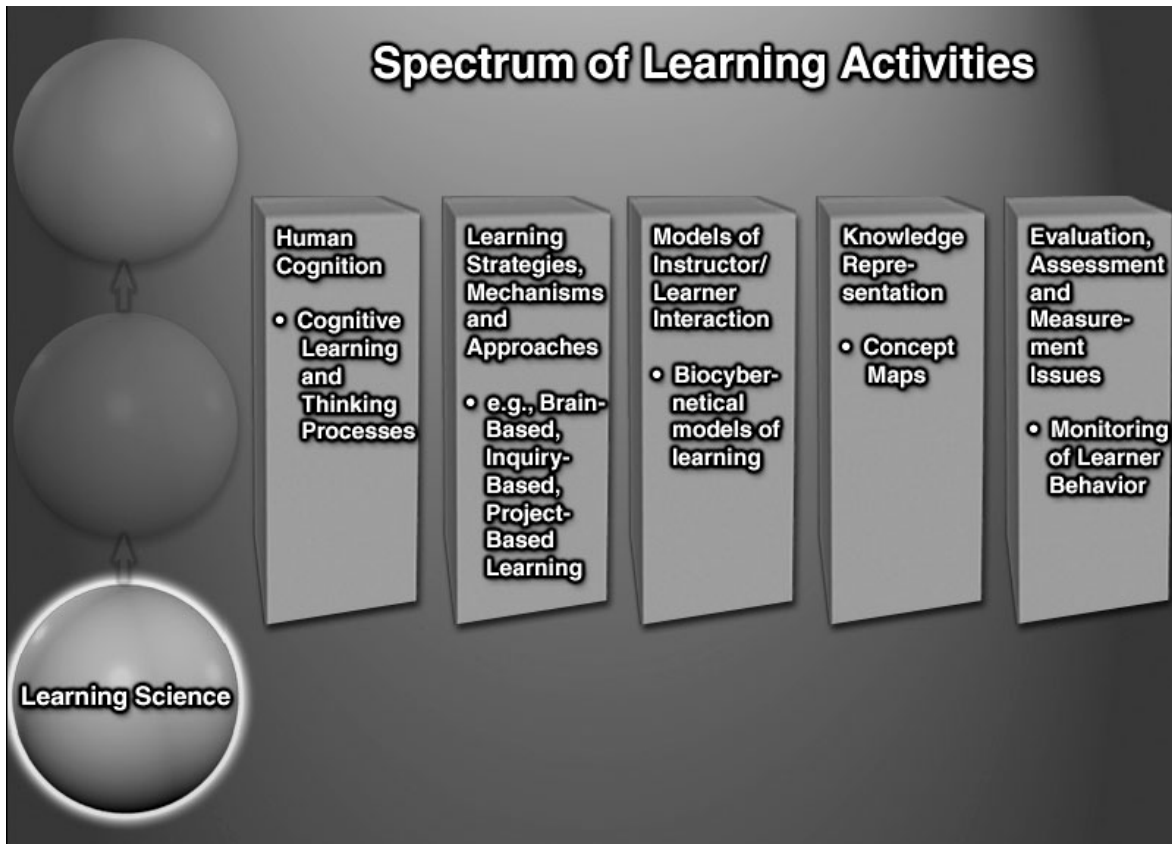
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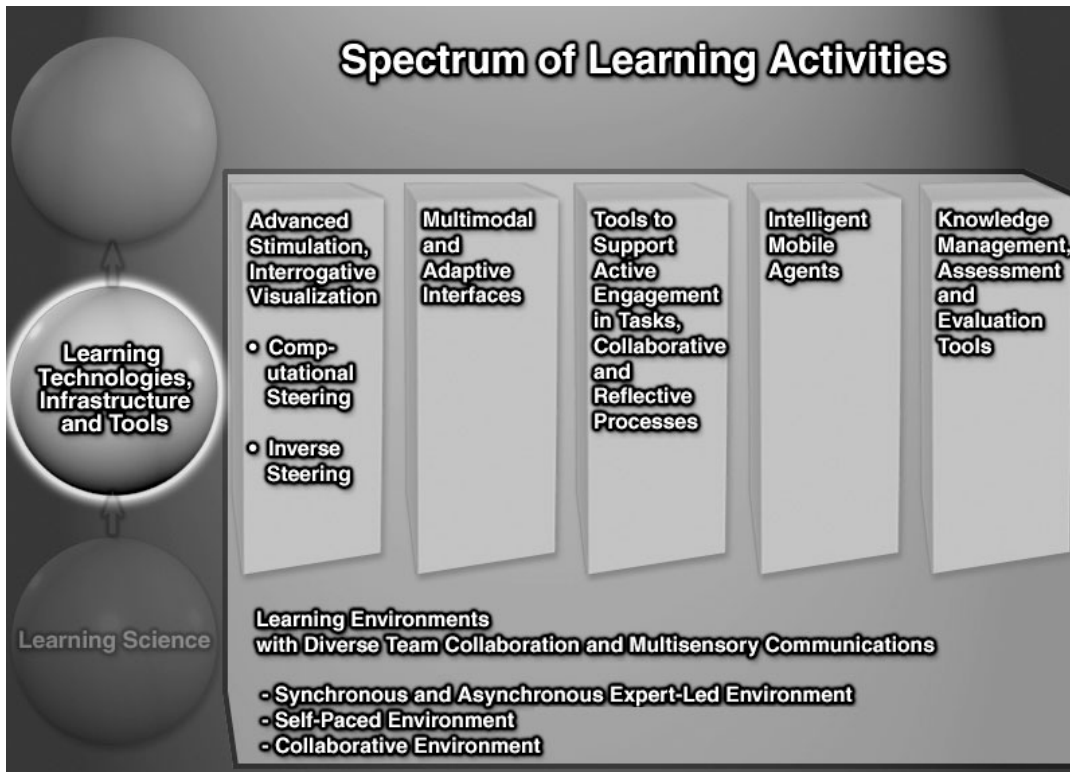
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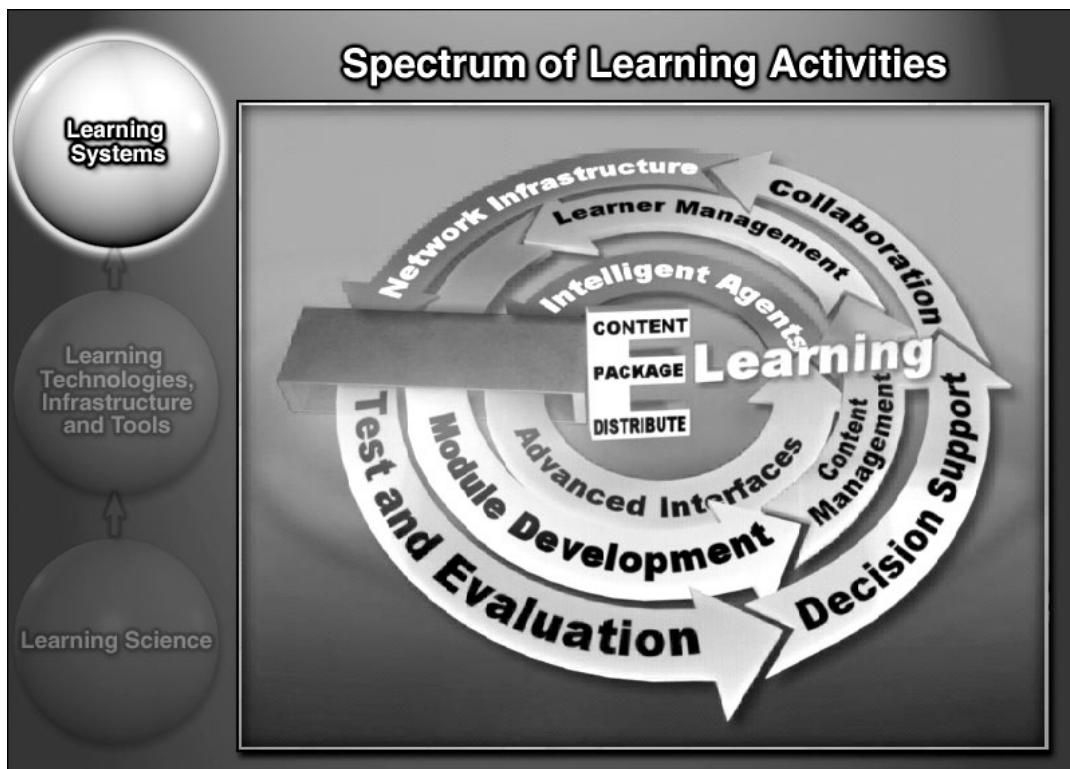
Figure 11c

RELEVANT TECHNOLOGIES

The development of advanced learning systems and learning networks require the synergistic coupling of a number of enabling and leading-edge technologies. These include (Figure 12): novel computing technologies/paradigms; high-capacity communication/networking; human/computer/network interfaces; instructional; information/knowledge; intelligent software agents; modeling, simulation and visualization; cognitive systems and; human performance.
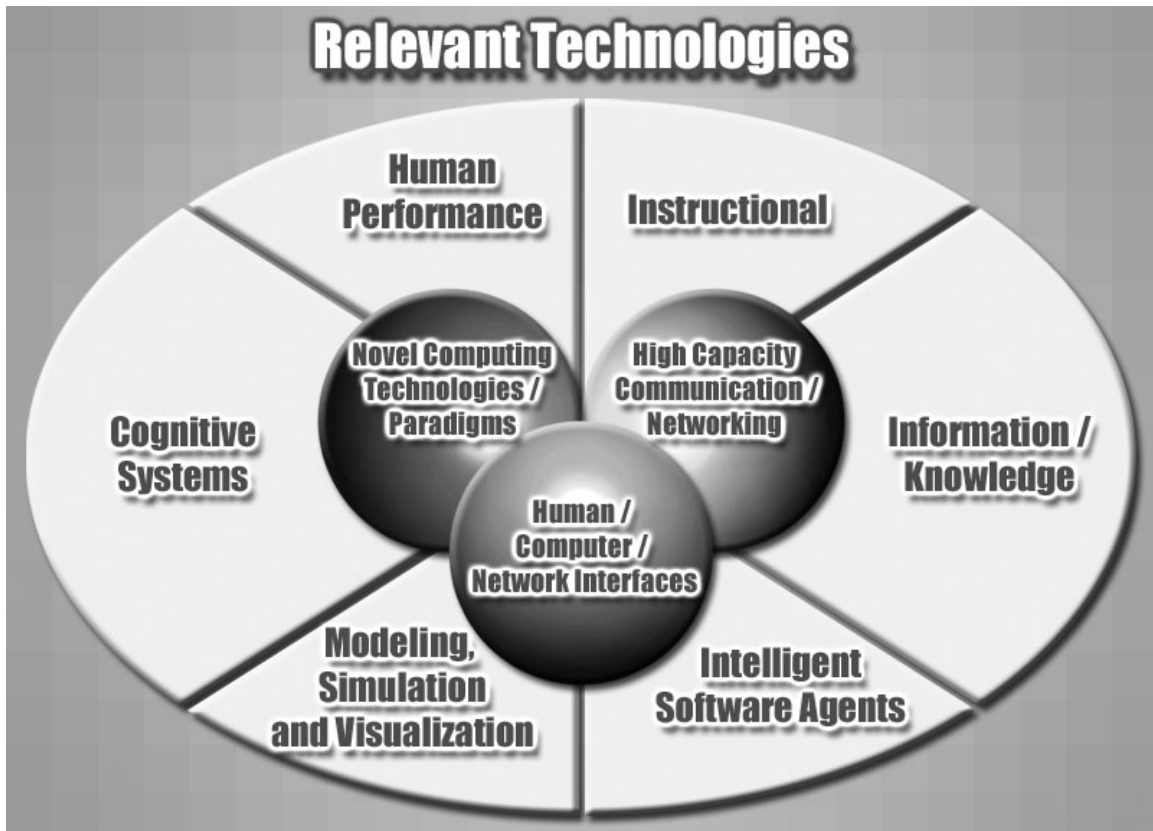
Figure 12

GOVERNMENT AND NON-GOVERNMENT ACTIVITIES

A number of government and non-government activities in the areas of advanced learning technologies and learning environments are currently underway. The government activities include (Figure 13): Advanced Distributed Learning (ADL) of DoD/OSTP; Adaptive Learning Systems of NIST; NSF Engineering Coalitions; e-Learning of the Department of Education and; Distance Learning of FGDL.

The non-government activities include MERLOT, FSRI's Advanced Learning Environments; University of Mississippi's Geospatial Information Coursework Development; MIT Open/Courseware Project; American Society for Training and Development (ASTD); United State Distance Learning Association (USDLA); Aviation Industry CBT Committee (AICC); and, The Training Place.
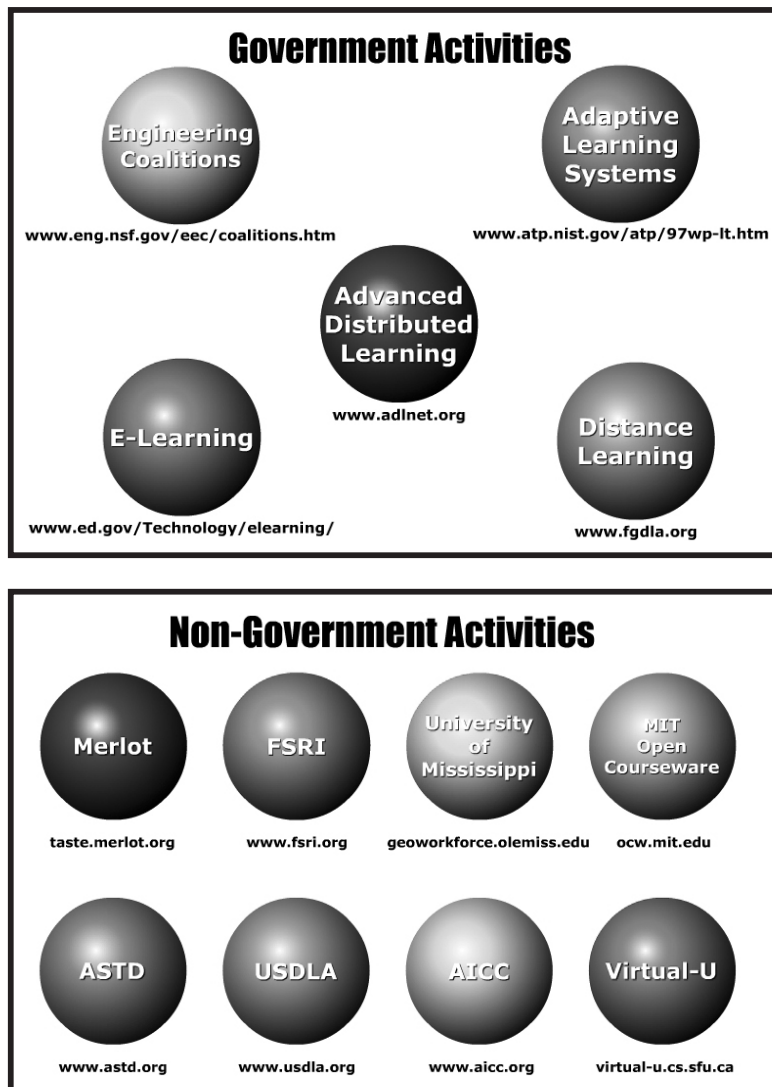
Figure 13

LEARNING TECHNOLOGY VENDORS

A list of some of the learning technology vendors is given in Figure 14. These include WBT, Mentorware, Pathlore, Avilar, Elluminate, and the Training Place.

Figure 14

TECHNICAL STANDARDS

Faced with a multiplicity of learning applications on the web, various initiatives can be found defining sets of metadata for describing them. It is of critical importance for the instructors and learners to find the learning materials when needed. This prompted a number of organizations to develop accredited technical standards, specifications, recommended practices and guides for learning technology. These include (Figure 15), the Sharable Content Object Reference Model (SCORM) of ADL; IEEE Learning Object Metadata (LOM) Standard and; the Learning Technology Standards of the Center for Educational Technology Interoperability Standards.
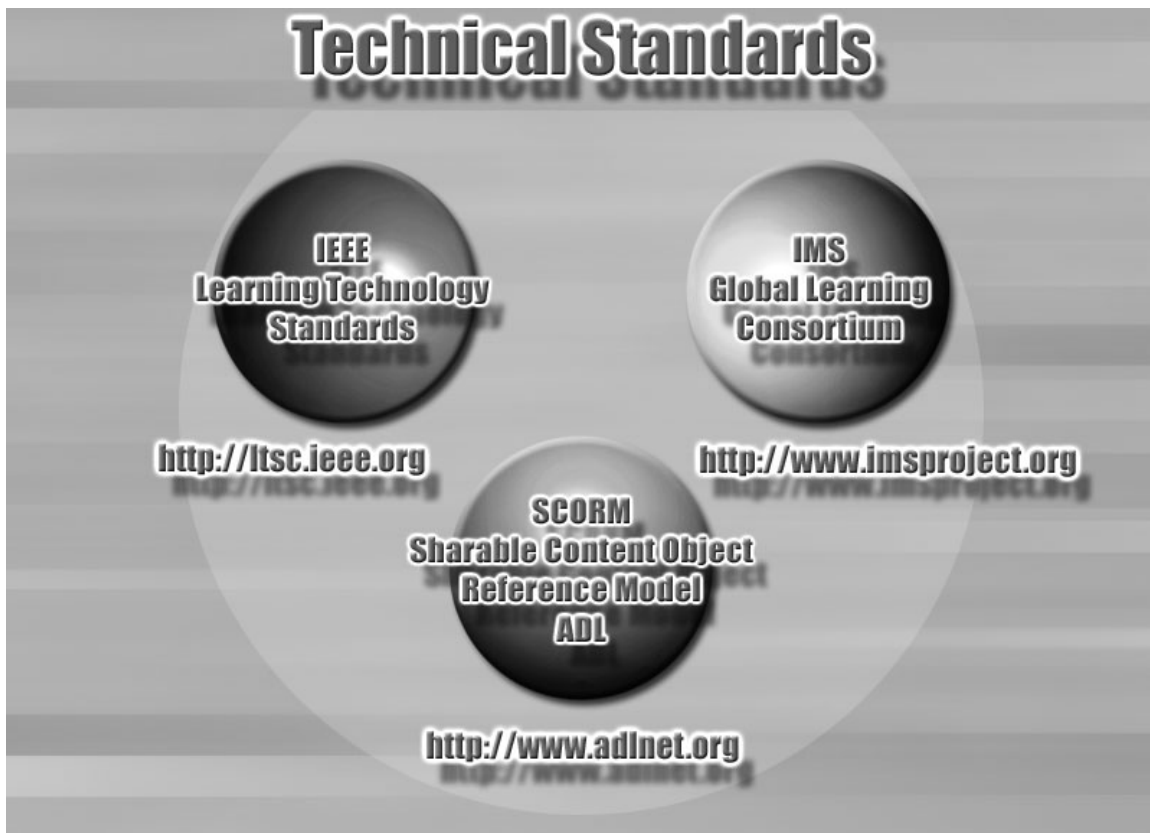
Figure 15

KEY COMPONENTS OF ADVANCED
MODELING AND SIMULATION ENVIRONMENT

The realization of the strategic value of modeling and simulation in learning systems requires an environment that links diverse teams of scientists, engineers and technologists. The essential components of the environment can be grouped into three categories: intelligent tools and facilities, nontraditional methods, and advanced interfaces (Figure 16). The three categories are described subsequently.
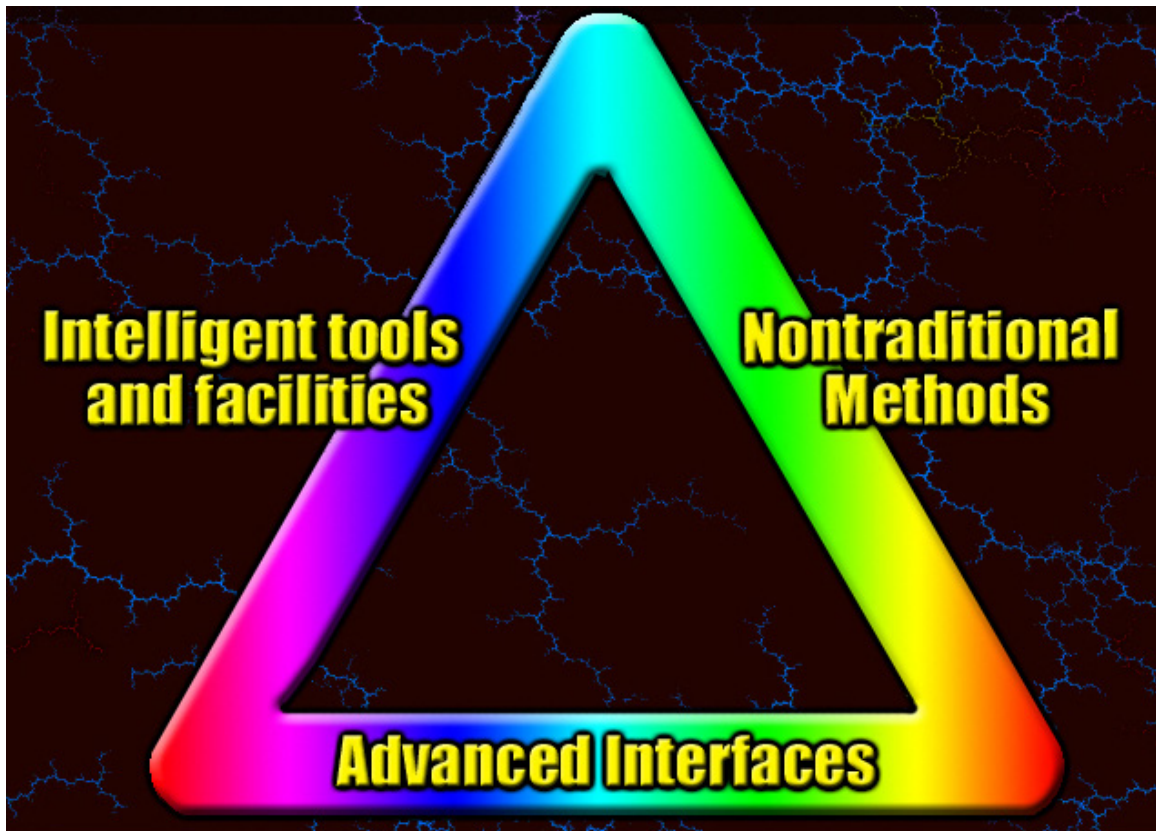
Figure 16

INTELLIGENT TOOLS AND FACILITIES

These include high fidelity – rapid modeling, simulation and interrogative visualization tools, synthetic immersive environments; close coupling of simulations and experiments; computer simulation of physical experiments and remote control of these experiments. In all of these tools, extensive use should be made of intelligent software agents and information technology (Figure 17).

Figure 17

EXAMPLES OF FUTURE AEROSPACE SYSTEMS AND SOME OF THEIR CHARACTERISTICS

The realization of NASA's ambitious goals in aeronautics and space with the current national budget constraints will require new kinds of aerospace systems and missions that use novel technologies and manage risk in new ways. Future aerospace systems must be autonomous, evolvable, resilient, and highly distributed. Two examples are given in Figure 18. The first is a biologically inspired aircraft with self-healing wings that flex and react like living organisms. It is built of a multifunctional material with fully integrated sensing and actuation, and unprecedented levels of aerodynamic efficiencies and aircraft control. The second is an integrated human-robotic outpost, with biologically inspired robots. The robots could enhance the astronaut's capabilities to do large-scale mapping, detailed exploration of regions of interest, and automated sampling of rocks and soil. They could enhance the safety of the astronauts by alerting them to mistakes before they are made, and letting them know when they are showing signs of fatigue, even if they are not aware of it.

Figure 18

23

ENABLING TECHNOLOGIES FOR FUTURE AEROSPACE SYSTEMS

The characteristics of future aerospace systems identified in Figure 18 are highly coupled and require the synergistic coupling of the revolutionary and other leading-edge technologies listed in Figure 19. The four revolutionary technologies are: nanotechnology, biotechnology, information/knowledge technology, and cognitive systems technology. The other leading-edge technologies are high-productivity computing; high-capacity communication; multiscale modeling, simulation and visualization; virtual product development; intelligent software agents; reliability and risk management; human performance, and human-computer symbiosis.
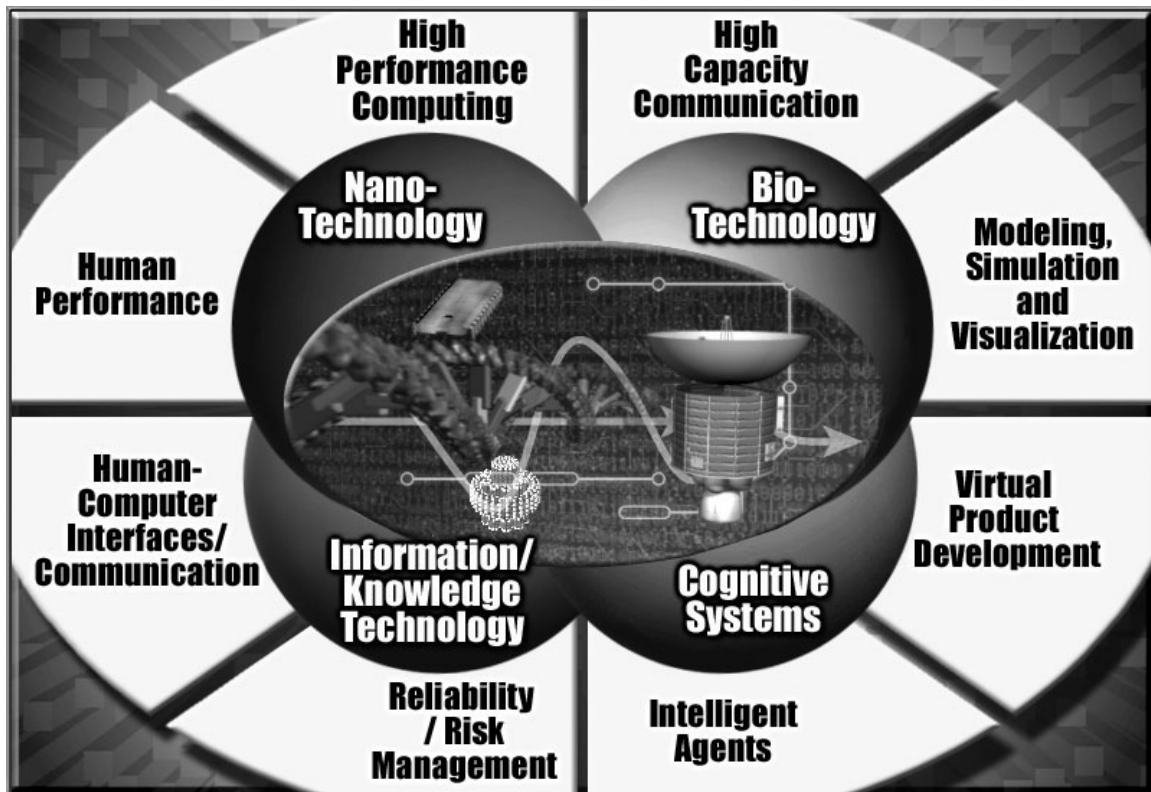
Figure 19

THREE NASA INITIATIVES

The realization of NASA's ambitious goals will require a diverse, technically skilled workforce – a new generation of scientists and engineers who can work across traditional disciplines and perform in a rapidly changing environment.

NASA has developed a number of new initiatives for assured workforce development. These include: University Research, Engineering, and Technology Institutes (URETIs), the National Institute of Aerospace (NIA), and the Hierarchical Research and Learning Network (HRLN) (see Figure 20). The overall goal of these activities is to strengthen NASA's ties to the academic community through long-term sustained investment in areas of innovative and long-term technology critical to future aerospace systems and missions. At the same time, the three activities will enhance and broaden the capability of the nation's universities to meet the needs of NASA's science and technology programs.
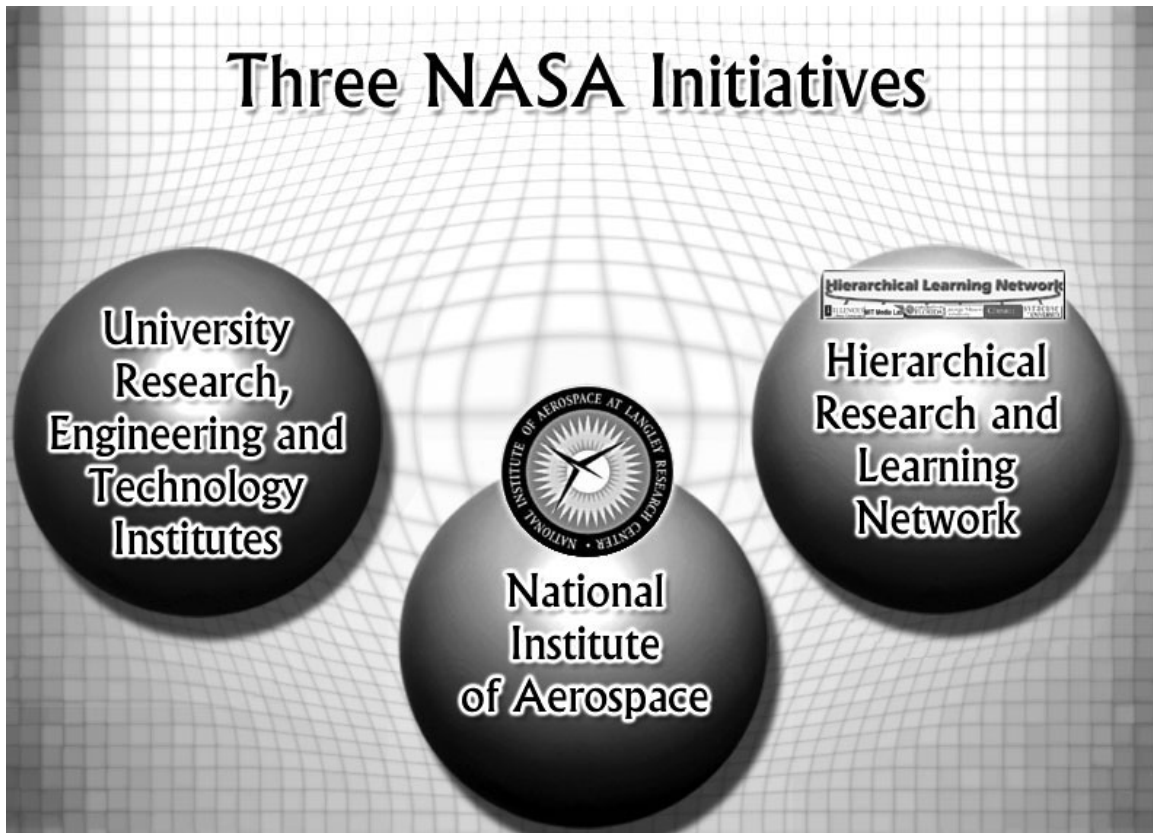
Figure 20

HIERARCHICAL RESEARCH AND LEARNING NETWORK

The Hierarchical Research and Learning Network (HRLN) is a pathfinder project for the future aerospace workforce development. It aims at creating knowledge organizations in revolutionary technology areas which enable collective intelligence, innovation and creativity to bear on the increasing complexity of future aerospace systems. This is accomplished by building research and learning networks linking diverse interdisciplinary teams from NASA and other government agencies with universities, industry, technology providers, and professional societies (Figure 21) in each of the revolutionary technology areas and integrating them into the HRLN.

HRLN is envisioned as a neural network of networks. It is being developed by eight university teams, led by Old Dominion University's Center for Advanced Engineering Environments.
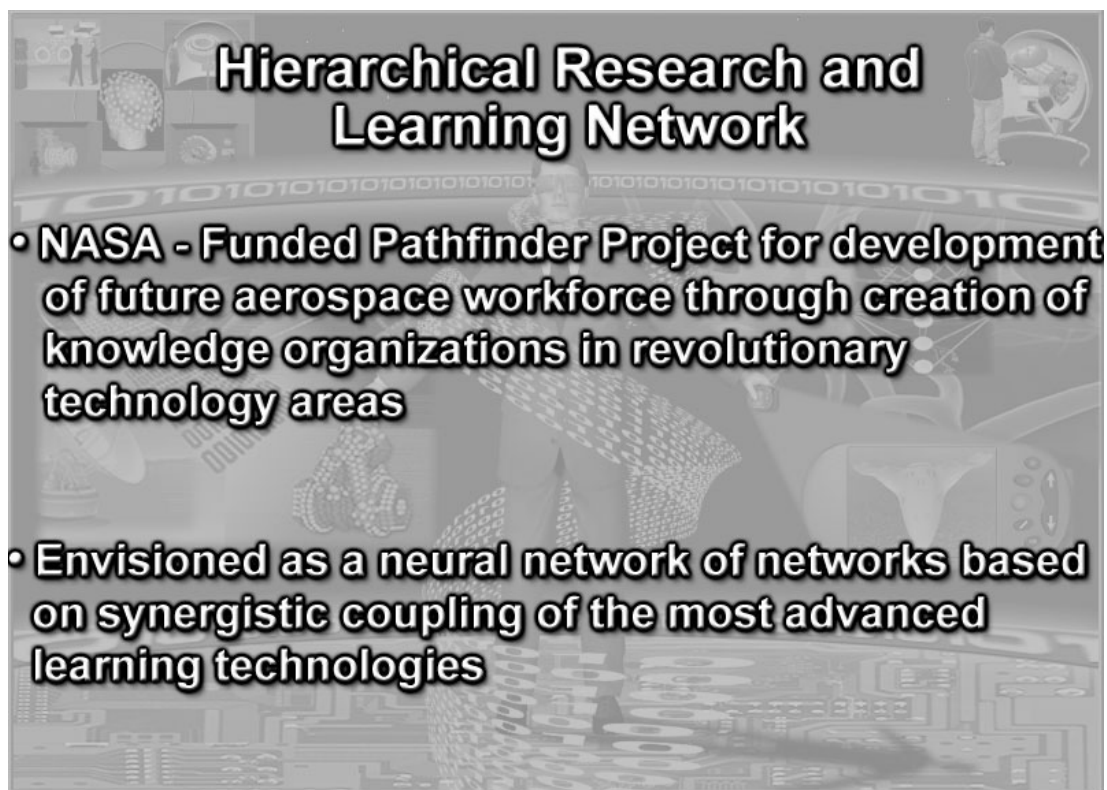
Figure 21
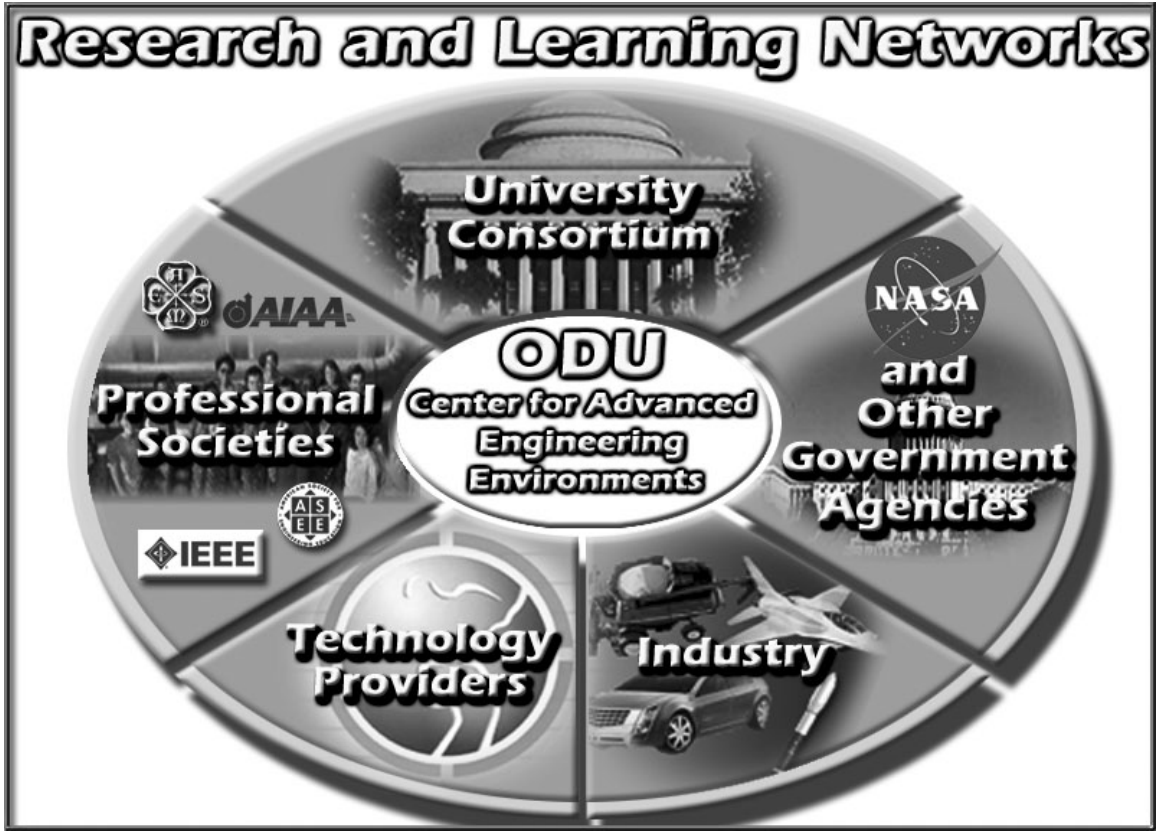
Figure 21 (continued)

IMPLEMENTAION OF HIERARCHICAL RESEARCH
AND LEARNING NETWORK

The phases of implementing HRLN are shown in Figure 22. The first phase involves development of learning modules and interactive virtual classrooms in revolutionary technology areas, simulators of unique test facilities at NASA, and a telescience system – an online multi-site lab that allows real-time exchange of information and remote operation of instrumentation by geographically distributed teams. These facilities will be integrated into adaptive web learning portals in the second phase, which evolve into robust learning networks. In the final phase, the learning networks are integrated into the HRLN.
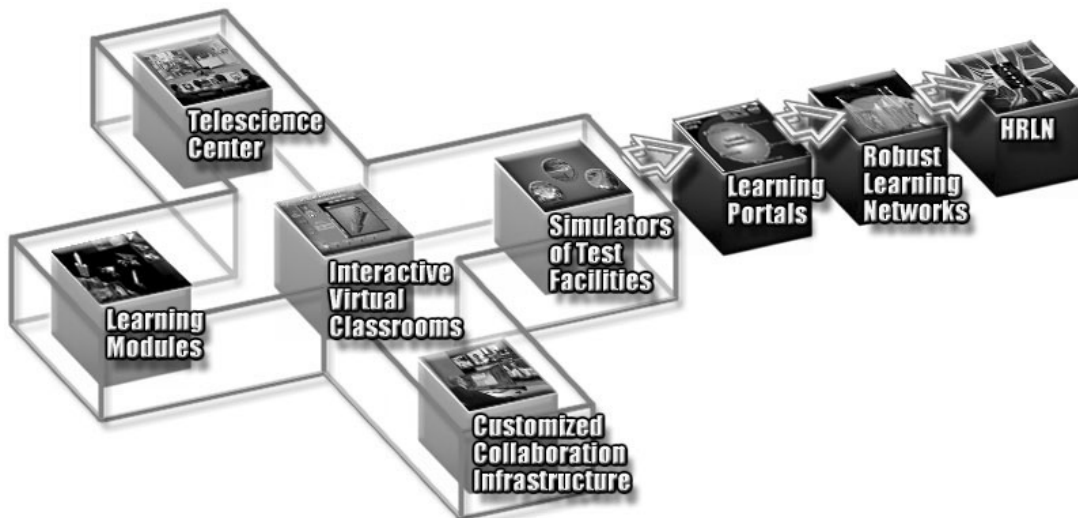
Figure 22

ADAPTIVE WEB LEARNING PORTAL

The Adaptive Web Learning Portal being developed as part of the HRLN project has the following major components (Figure 23):

- Advanced multimodal interfaces,
- Knowledge repository,
- Blended learning environment incorporating the three environments: expert-managed, self-paced, and collaborative,
- Learning management system, and
- Customized collaboration infrastructure
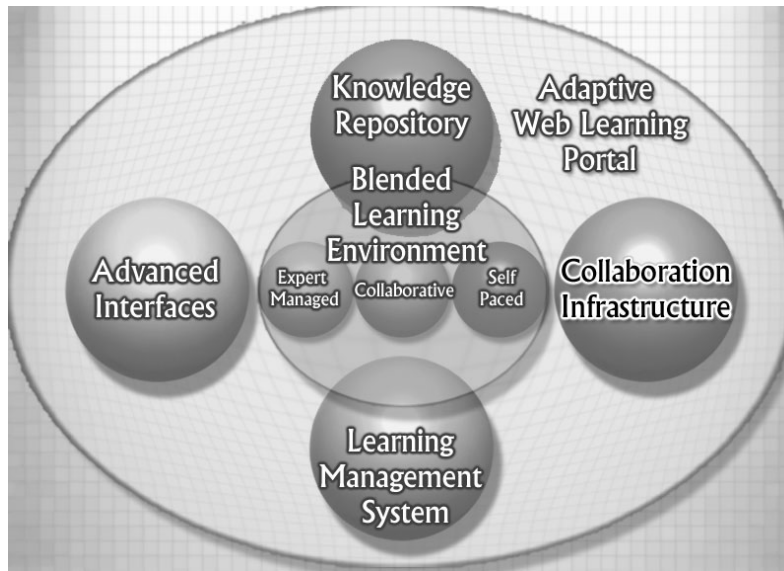
Figure 23

VIRTUAL CLASSROOM

Online training and virtual classrooms are typically used to provide learning environments with custom self-instruction, flexible tutorial support, and choice of both the place and time of learning. Three categories of facilities are used in these environments; namely: *instruction*, including multimedia lectures, links to other resources and tools for searching, browsing, and using archived knowledge; *communication*, including email, UseNet, chat centers, video and Internet conferencing; and *course management and performance evaluation* (Figure 24).
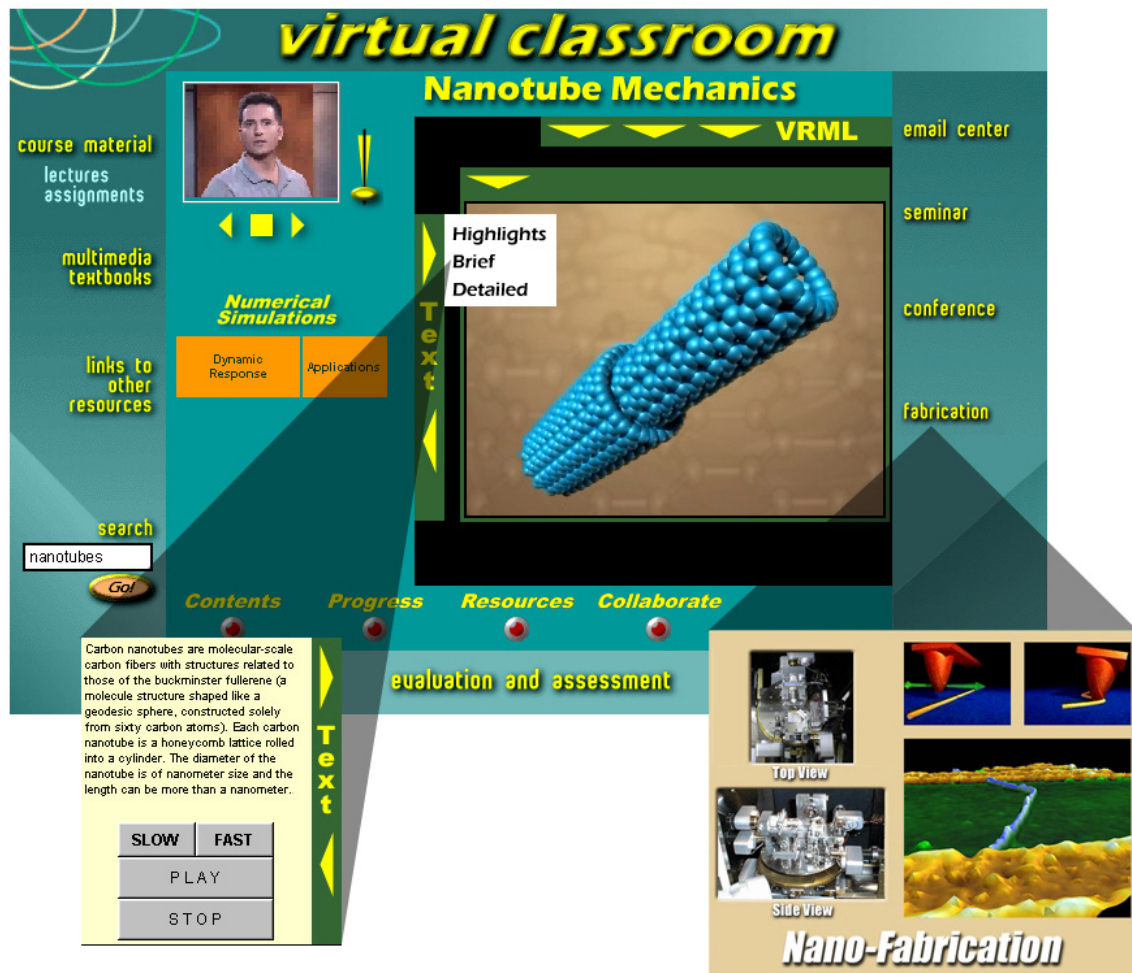
Figure 24

INTELLIGENT DESIGN ENVIRONMENT

The future design environment will enable collaborative distributed synthesis to be performed by geographically dispersed interdisciplinary/multidisciplinary teams. It will include flexible and dynamic roomware (active spaces/collaboration landscape) facilities consisting of (Figure 25):

- Portable and stationary information devices
- Novel multiuser smart displays
- Telepresence and other distributed collaboration facilities
- Novel forms of multimodal human/network interfaces
- Middleware infrastructures and intelligent software agents

Figure 25

31
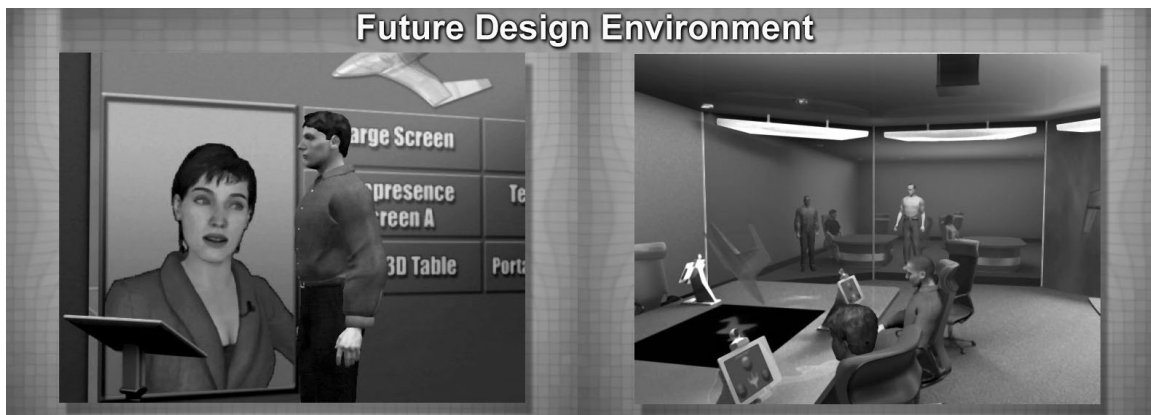
OBJECTIVES AND FORMAT OF WORKSHOP

The objectives of the workshop are to (Figure 26): a) provide broad overviews of the diverse activities related to advanced learning technologies and learning environments; and b) identify future directions for research that have high potential for future aerospace workforce development. The format included eighteen half-hour presentations in eight sessions.

- Objectives:
    - Overview of the diverse activities related to advanced learning technologies and learning environments
    - Identify future directions for research that have high potential for future aerospace workforce development

- *Format:*
    - 18 presentations; 8 sessions

- *Proceedings:*
    - NASA Conference Proceeding

Figure 26

INFORMATION ON ADVANCED LEARNING TECHNOLOGIES AND LEARNING ENVIRONMENTS

A short list of recent books, monographs, and reports on advanced learning technologies and learning environments is given subsequently.

[1]   "*Distributed Education: Summary of a Six-Part Series*", American Council on Education, Washington, DC, 2003.
[2]   Levine, A. and Sun, J.C., "*Barriers to Distance Education*", American Council on Education, Washington, DC, 2003.
[3]   Katz, R.N., "*WEB Portals and Higher Education: Technologies to make IT personal*", EDUCAUSE, National Association of College and University Business Officers, San Francisco, CA, Jossey-Bass, 2002.
[4]   Berg, G.A., "*Why Distance Learning – Higher Education Administration Practices*", Greenwood Publishing Group, Inc., Westport, CT, 2002.
[5]   Johnstone, S.M., Ewell, P., and Paulson, K., "*Student Learning as Academic Currency*", American Council on Education, Washington, DC, 2002.
[6]   Katz, R.N., Ferrara, E.M., and Napier, I.S., "*Partnerships in Distributed Education*", American Council on Education, Washington, DC, 2002.
[7]   Eaton, J.S., "*Maintaining the Delicate Balance: Distance Learning, Higher Education Accreditation, and the Politics of Self-Regulation*", American Council on Education, Washington, DC, 2002.
[8]   Hitt, J.C., and Hartman, J.L., "*Distributed Learning: New Challenges and Opportunities for Institutional Leadership*", American Council on Education, Washington, DC, 2002.
[9]   Laurillard, D., "*Rethinking university teaching: a conversational framework for the effective use of learning technologies*", RoutledgeFalmer, London, 2002.
[10]   Oblinger, D.G., Barone, C.A., and Hawkins, B.L., "*Distributed Education and its Challenges: An overview*", American Council on Education, Washington, DC, 2001.
[11]   Collis, B and Moonen, J., "*Flexible Learning in a Digital World: Experience and expectations*", Kogan Page, London, 2001.
[12]   Lockwood, F. (editor) and Gooley, A., "*learning*", Kogan Page, London, 2001.
[13]   Gray, J.N., et. al., "*Using Information Technology to Transform the Way We Learn*", [http://dlist.sir.arizone.edu/archive/00000047/], 2001.
[14]   "*Distributed Education and Its Challenges: An Overview*", American Council on Education, Washington, DC, 2001.
[15]   "*Using Information Technology to Transform the Way We Learn*", Report to the President, President's Information Technology Advisory Committee, Panel on Transforming Learning, 2001.
[16]   "*Digital Libraries: Universal Access to Human Knowledge*", Report to the President, President's Information Technology Advisory Committee, Panel on Transforming Learning, 2001.
[17]   Finkelstein, M.J., Frances, C., Jewett, F.I., Scholz, B.W., "*Dollars, Distance, and Online Education – The New Economics of College Teaching and Learning*", Greenwood Publishing Group, Inc., Westport, CT, 2000.

Optimizing Individual Learning Performance with Multidimensional Evaluations and Adaptive Systems

Nishikant Sonwalkar, PhD
Massachusetts Institute of Technology
Cambridge, MA

OPTIMIZING INDIVIDUAL LEARNING PERFORMANCE WITH MULTIDIMENSIONAL EVAULATIONS AND ADAPTIVE SYSTEMS

Dr. Nishikant (Nish) Sonwalkar is principal educational architect at the Academic Media Production Services center. He has been providing pedagogical guidance and supervision to many projects developed at MIT. He is co-author of the MIT first fluid mechanics hypercourse.
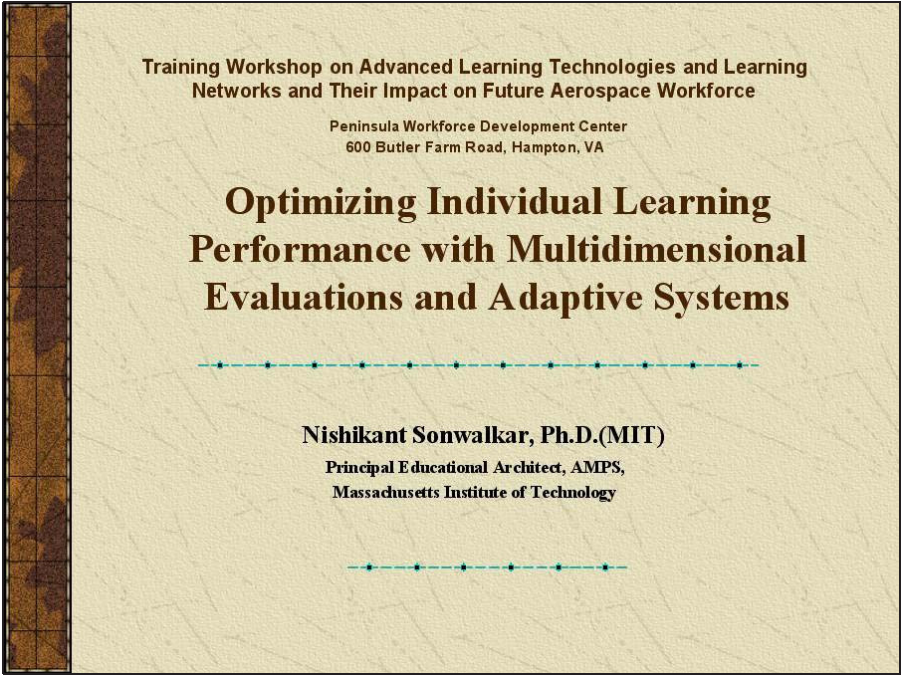
Figure 1

AGENDA
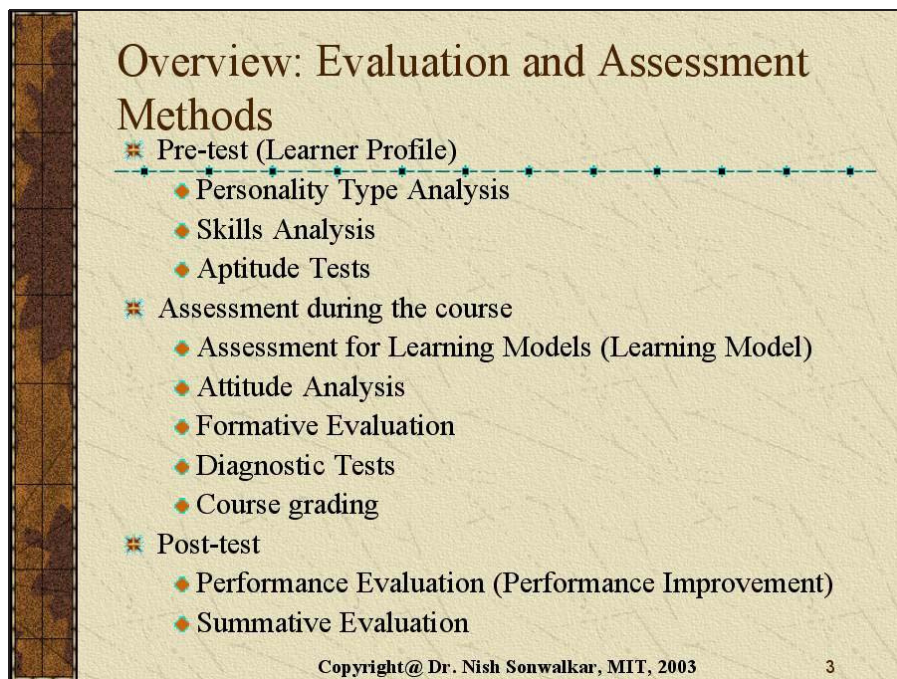
The technology enhanced learning is a multidimensional space that allows individual students learn with their own learning preferences. The individual preferences depend on the personality type that can be inferred using various Jungian psychological learning type descriptors. It is proposed by the presenters that correlations can be found between the personality type and the learning preference. The fundamental dimensions for the learning are, media, learning models, and interactivity. The main agenda of this presentation is describing a multi-dimensional evaluation model that can measure the pedagogical effectiveness of the on-line courses and measure individual performance. It is proposed that the correlations between personality types and learning preferences in the area of media, models and interactivity are then used to optimize the individual learning performance.

Figure 2

OVERVIEW: EVALUATION AND ASSESSMENT METHODS

       We begin with a brief survey of evaluation and assessment methodologies. The methodologies can be of represented in three categories, pretest, assessments and post test. The pre-test can help in defining learner profile in terms of personality types described by Jungian models such as Myers-Briggs, skills analysis and aptitude analysis, such as, SAT, GRE and finally skills gap analysis to ascertain the current level of skills for an individual. The assessment can be conducted during the learning activity for learning model preferences, attitude surveys, formative surveys, diagnostic tests on concepts, and course tests such as mid-terms and finals. The post-test, are performed to understand the summative effect of the learning and performance improvements.

Figure 3

PERSONALITY TYPE DISCRIPTORS: JUNGIAN MODELS

Most widely adopted model for personality type test is Myers-Briggs. This test was developed based on the personality type descriptions proposed by Jung and is conducted in the form of a detailed survey instrument that leads to personality type descriptions in the form of Extraversion or Introversion, Sensing perception and Intuitive perception, Thinking judgment or Feeling judgment, and judgment or perception. Based on these parameters the Myers-Briggs test describes sixteen personality types.

Figure 4

THE PERSONALITY TYPES BY MYERS-BRIGGS SURVEY

This table illustrates the sixteen personality types that can be assigned based on the survey instrument.

Figure 5

THE LEARNING MODELS

The learning models have evolved based on three psychological models, behavioral which is based on Skinners approach of stimulus/response approach, The cognitive psychology models such as induction, deduction and constructivist models proposing collaboration, incidental and self discovery models of learning.
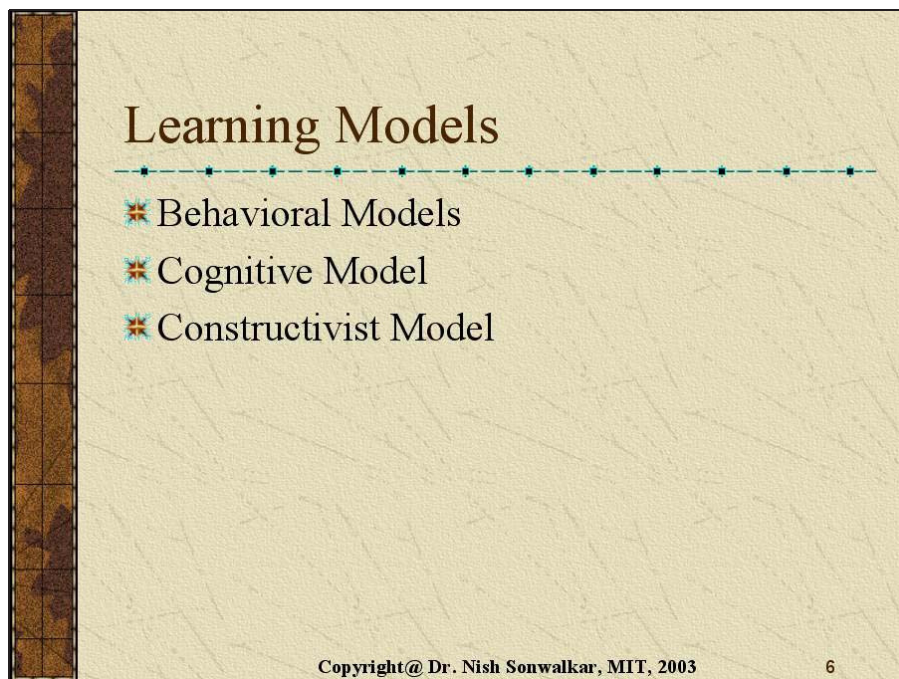
Figure 6

LEARNING THEORIES INFLUENCES

The learning theories that have influence the direction of technology enhanced and enabled learning platforms are: Skinners, behaviorist approach, Lev and Dewey, situated learning, Piaget and Brunner's constructivist model, Spriro's cognitive flexibility, Merrill et.al.'s component display and Gardner's multiple intelligence theory. These references all point towards multiple ways individual prefer to learn. These models have also led to learning style inventories to define the individual preferences on how instructions and content are organize to match the individual preference to receive knowledge.

Learning Theories and Strategies
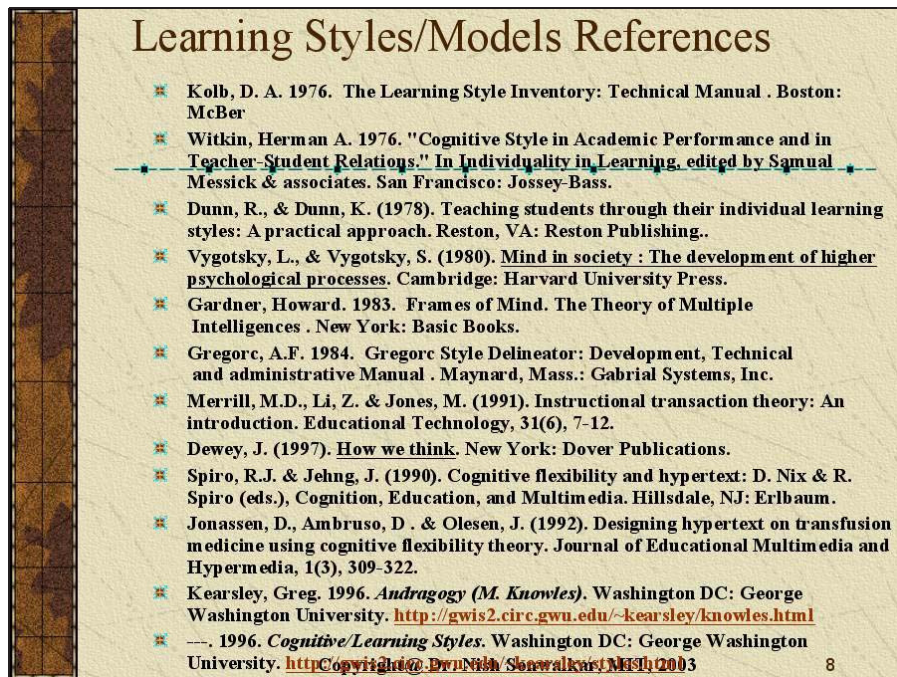
Behaviorist	Stimulus/response	Skinner et. al.
Situated	cognitive apprenticeship	Lev, Dewey
Constructivist	collaborative, incidental, discovery	Piaget, Brunner
Cognitive Flexibility	inductive reasoning	Spiro et. al.
Component Display	deductive reasoning	Merrill et al
Multiple Intelligence	Multiple intelligence	Gardner

Figure 7

THE RESEARCH PAPERS ON LEARNING STYLES AND STRATEGIES

Some of the seminal papers and references are given in this figure for those who would like to pursue study in the area of learning styles and models.

Figure 8

THE LEARNING CUBE: THE 3-D OF LEARNING

The learning cube model is a attempt to propose an integrative multi-dimensional framework for design and development of pedagogically effective technology enabled and enhanced learning modules. The y-axis describes the media preferences, such as, text, graphics, audio, video, animations and simulations. The x-axis describes the learning model that are taken form all three psychological theories namely, apprentice, incidental, inductive, deductive and discovery. The z-axis describes various modes of interactivity, such as, intelligent feedback, remediation, discussion, dialogue and discourse. It is proposed by the presenter that all three dimensions play equally important role in enhancing the learning process. The pedagogical effectiveness then can be defined in terms of available choices to learners provided in these three dimensions.
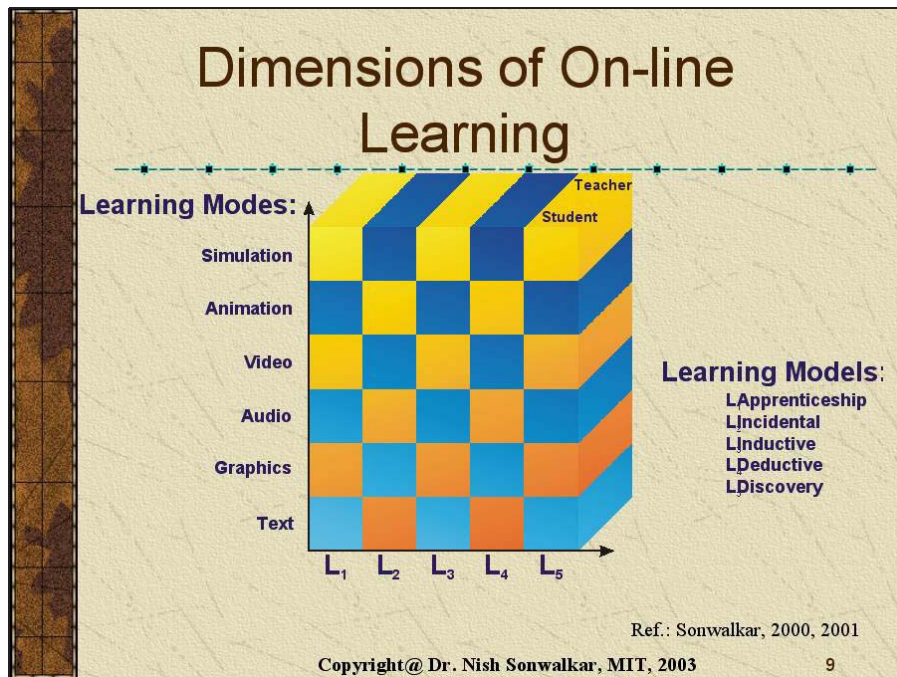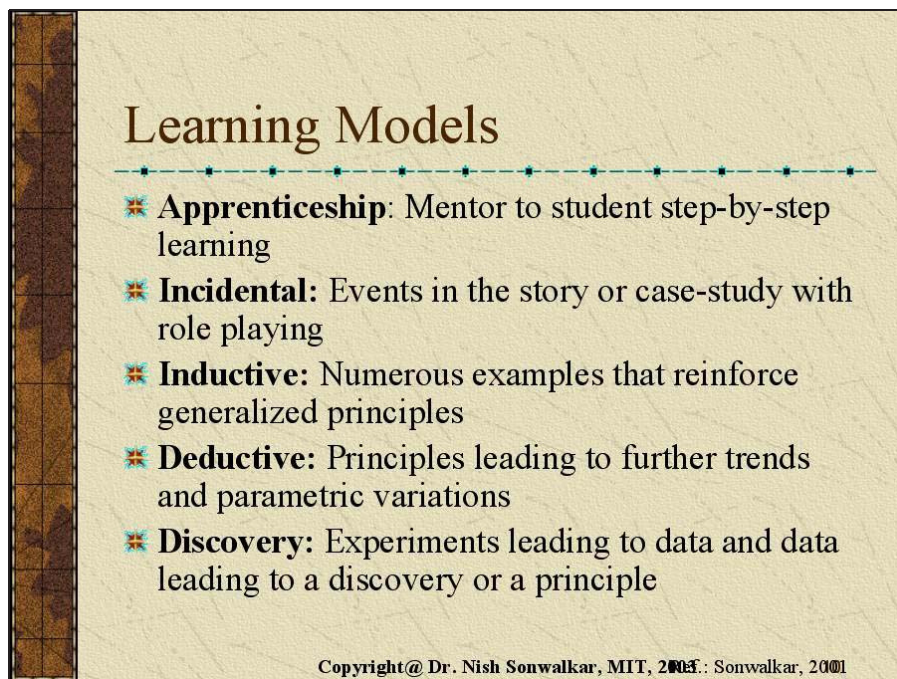
Figure 9

THE FUNCTIONAL LEARNING MODELS FOR ON-LINE LEARNING

The short definition of functional learning models that can be adopted for the on-line learning paradigm are provided in this figure.

Learning Models
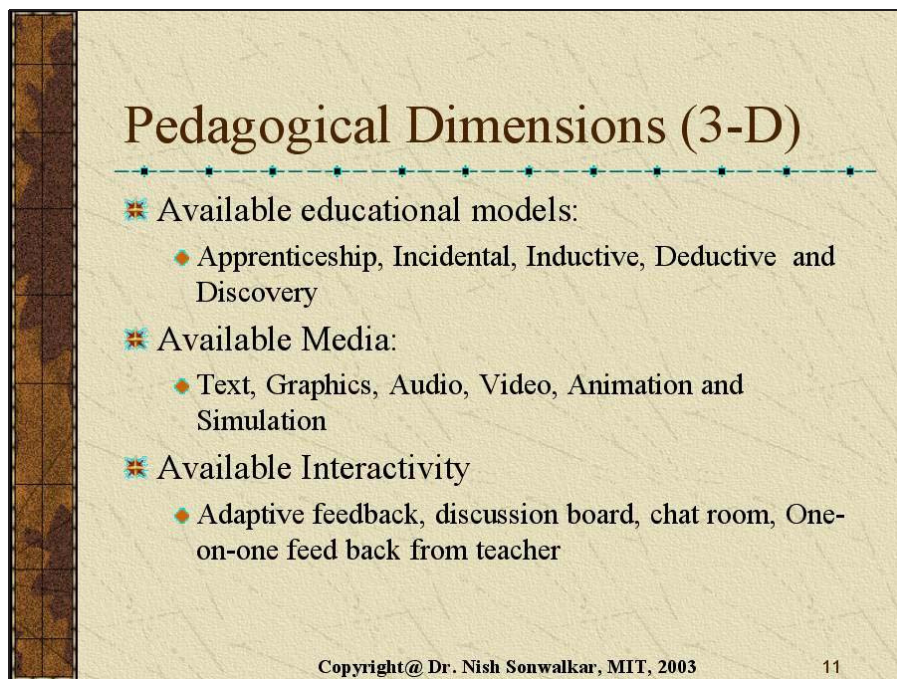
* **Apprenticeship**: Mentor to student step-by-step learning
* **Incidental:** Events in the story or case-study with role playing
* **Inductive:** Numerous examples that reinforce generalized principles
* **Deductive:** Principles leading to further trends and parametric variations
* **Discovery:** Experiments leading to data and data leading to a discovery or a principle

Figure 10

THE AVAILABLE CHOICES IN THE 3-DIMENSIONS OF LEARNING

Three primary dimensions for the pedagogy are defined in term of choices that can be offered to learners based on the media, models and interactivity.

Figure 11

MEASURING PERFORMANCE WITH KIRKPATRICK METHOD

The performance measure are defined for the training program based on the four level analysis proposed by Kirkpatrick, that defines first level as the reaction of a learner towards the training program and their current performance, the level II instruments evaluate the learning outcome in terms of performance improvements and retention of the performance as a result of the training program the level II instruments evaluate the behavioral change subsequent to the training program for performance and retention of the behavioral change for performance and the level IV evaluates the organizational impact of the training program and evaluation of the return on investment (ROI) based on organizational performance.

Measuring Performance: Kirkpatrick Model

Level I - Reactions

Level II - Learning

Level III - Behavior

Level IV - Results

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Figure 12

48
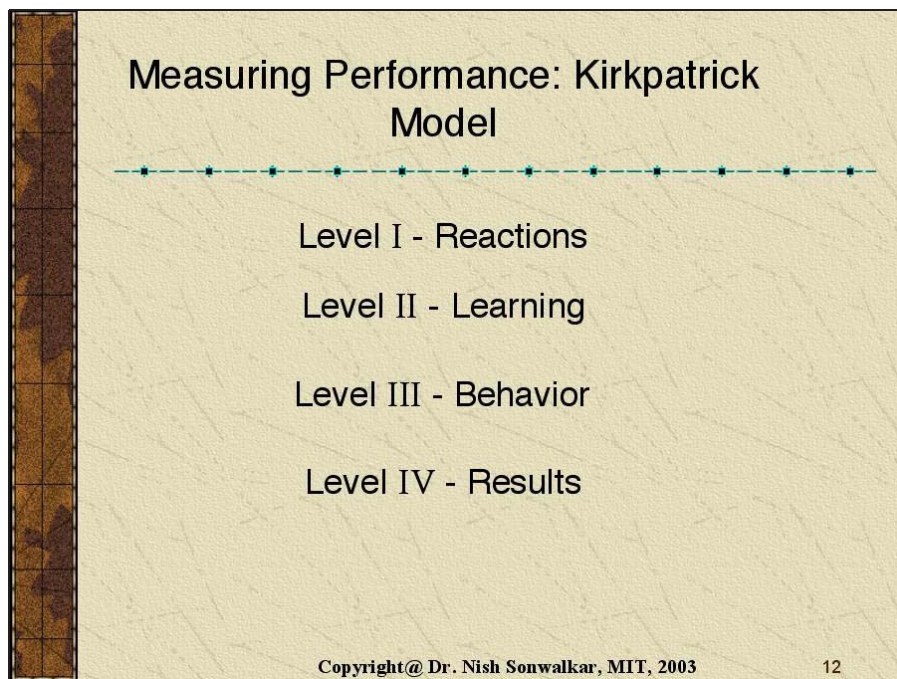
PERFORMANCE OPTIMIZATION FOR INDIVIDUALS

The goal for the individual performance optimization is offer on-line learning modules that lead to higher motivation by providing engaging learning interface. The adaptive learning model by delivering the learning modules that match the learning preferences then can minimize the time to learn. The learning that has engaging interface will also lead to longer retention for the learning. These three variables, motivation, time to master the concepts and retention once optimized for an individual will lead to desired improvement in the performance leading to measurable return on investment (ROI)..

Figure 13

ADAPTIVE LEARNING MODEL

The optimization of the individual performance is achieved by providing continuous adaptive remediation of the conceptual difficulties. The remediation is done at the concept level. Each concept has a diagnostic test. The diagnostic test determines the level of mastery for a given concept. Based on the performance in the diagnostic test first the concept deficiencies are identified and then the remedial content is represented in different learning style. This is equivalent to rotating the learning cube until best learning style statistically identified for the learner.

Figure 14

50
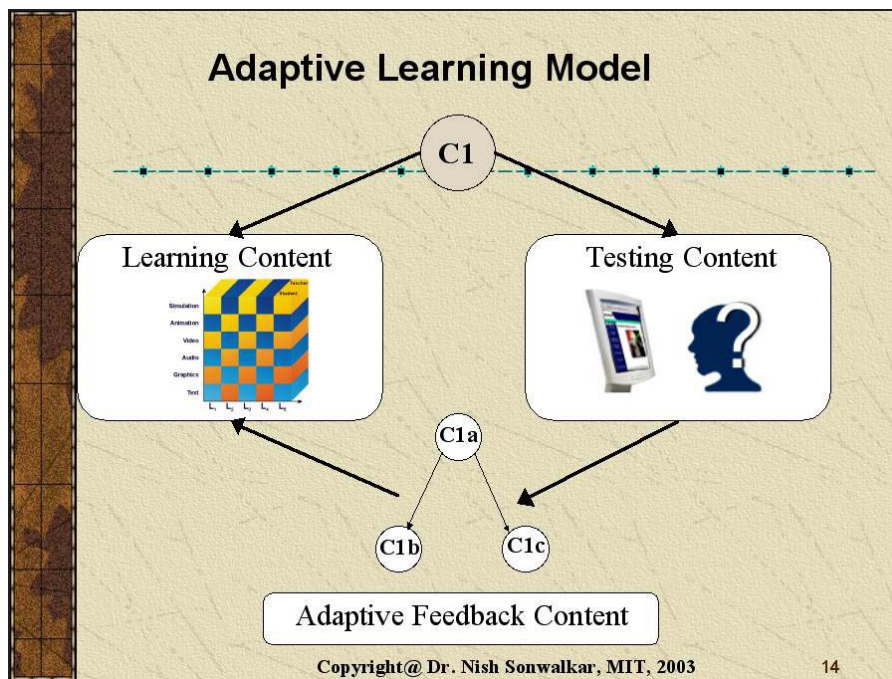
The multi-dimensional evaluation can now be performed based on a simple probability tree diagram based on the assumption that media, models, and interactivity elements described in the learning cube contribute equally and learning events are mutually exclusive and equally likely. A simple probability distribution for the media, model and interactivity events then can be represented by summation of individual events.

It is important to note that the pedagogical effectiveness depends on all three fundamental dimensions of the learning cube.
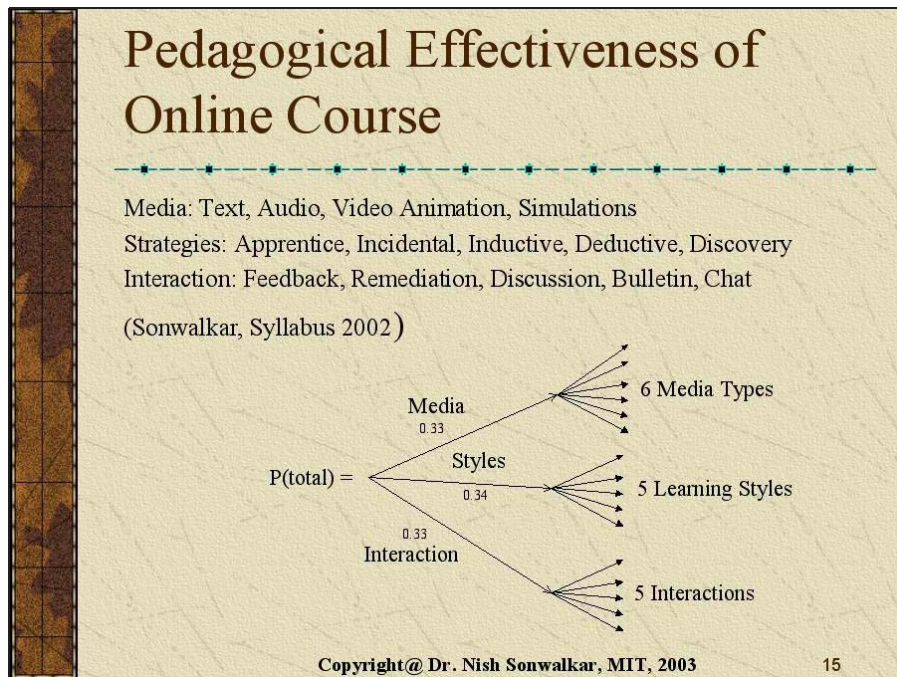
Figure 15

THE PEDAGOGICAL EFFECTIVENESS INDEX

The Pedagogical Effectiveness Index (PEI) can be represented by a simple probability summation model based on the number of media elements, number of learning model elements and number of interactivity elements. The PEI index, therefore increases with the availability of the events.
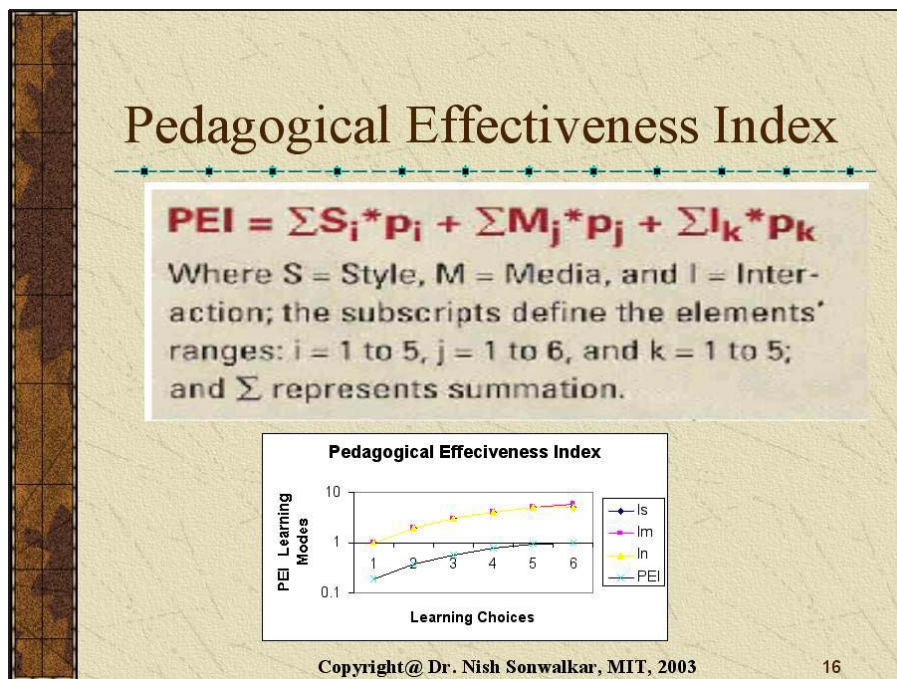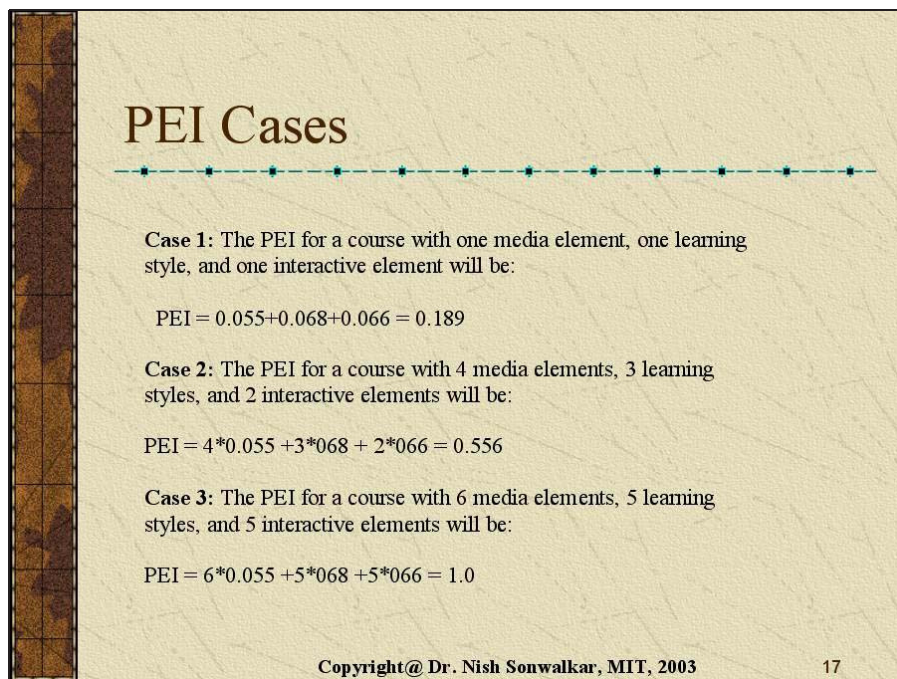
Figure 16

Three cases to demonstrate how PEI model can be applied to evaluate effectiveness of the learning modules with the integration of different media, model and interactivity elements.

Figure 17

EVALUATING LEARNERS EXPERIENCE: FIVE FACTORED SUMMATIVE INSTRUMENT

The learners experience can be evaluated based on the five-factored summative evaluation survey instrument. The five factors include content factors, learning factors, delivery support factors, usability factors and technological factors.

Influencing Factors: Learner experience

- Content Factors
- Learning Factors
- Delivery Support Factors
- Usability Factors
- Technological Factor

(Sonwalkar, Syllabus Jan 2002)

Figure 18

THE CONTENT FACTORS

The elements of the content factors ascertain the content is prepared with high quality and is authenticated by the reliable sources. The content also includes various multi-media elements, presentation style and attribution to the source of information.
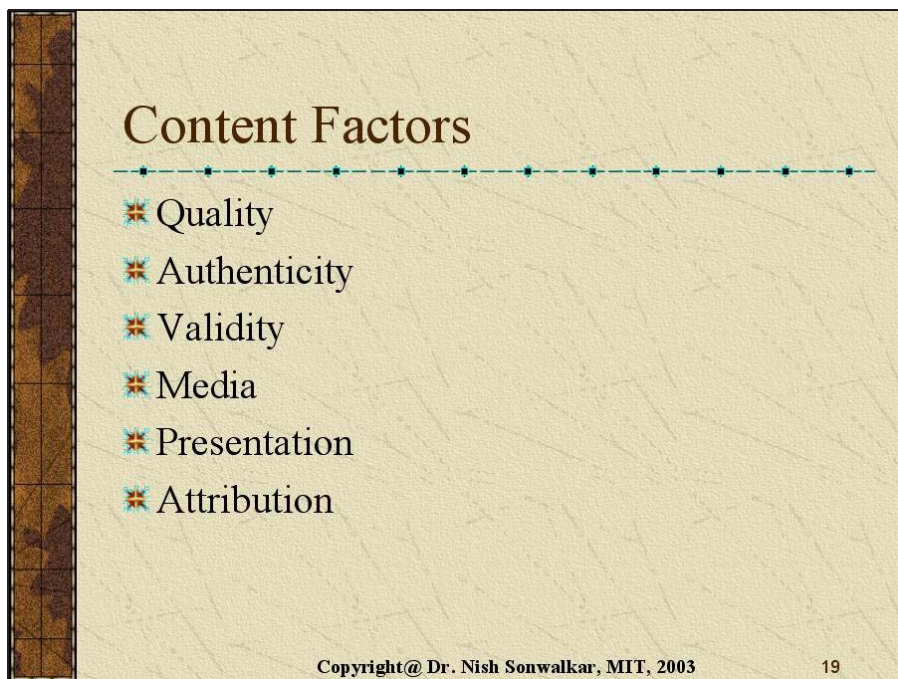
Figure 19

THE LEARNING FACTORS

The content has to be organized with concept map that defines the content with the correct concept structure, pedagogically driven instructional design developing content sequencing for different learning models described earlier, media enhancements to accommodate audio, visual and kinesthetic experience, interactivity with peers, professors and practitioners, intelligent feedback for remediation and revisions and collaboration with a team of co-learners.
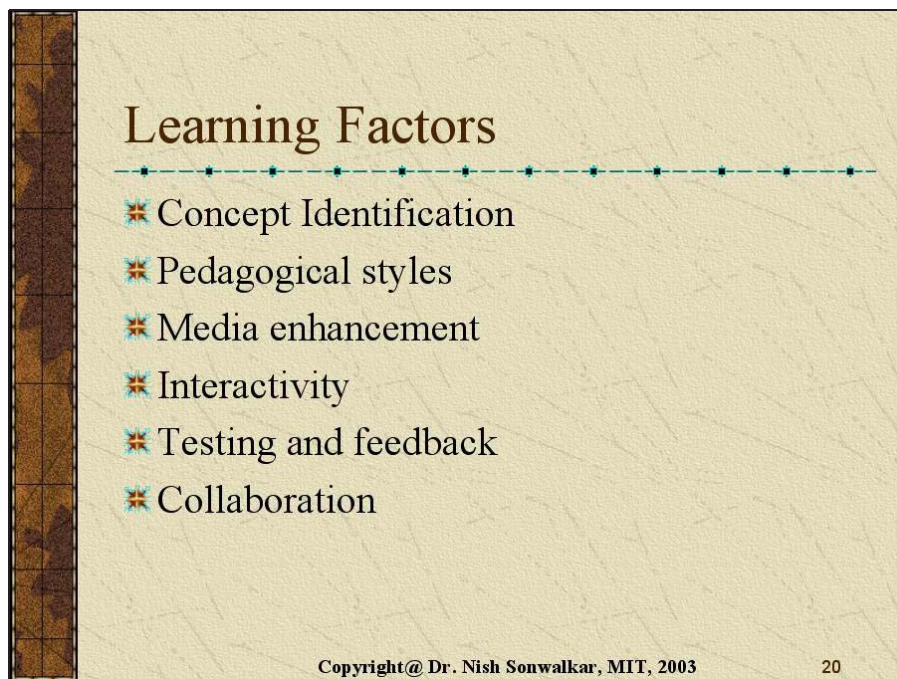
Figure 20

DELIVERY SUPPORT FACTORS

For the on-line offering the delivery support systems are very important. The learning management system, content management, accessibility standards 504, 508 needs to be implemented. Extensive reporting of the student activities is recorded by the delivery support systems.
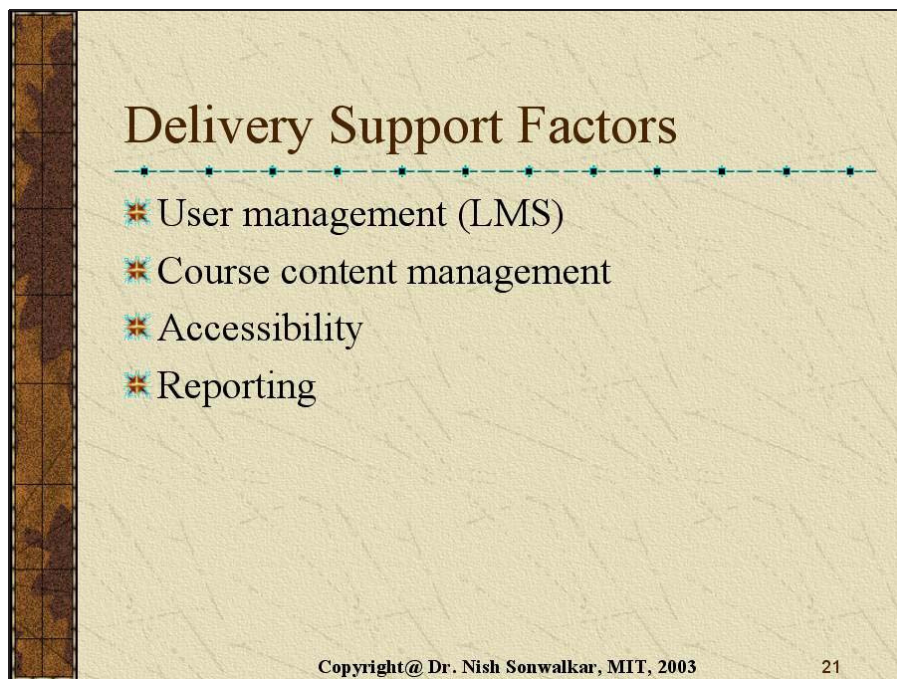
Figure 21

THE USABILITY FACTORS

The usability of the on-line module depends heavily on the graphical user interface, interactivity, clarity, chunk size and page layout. Learners input to these elements is important to determine success an on-line offering.
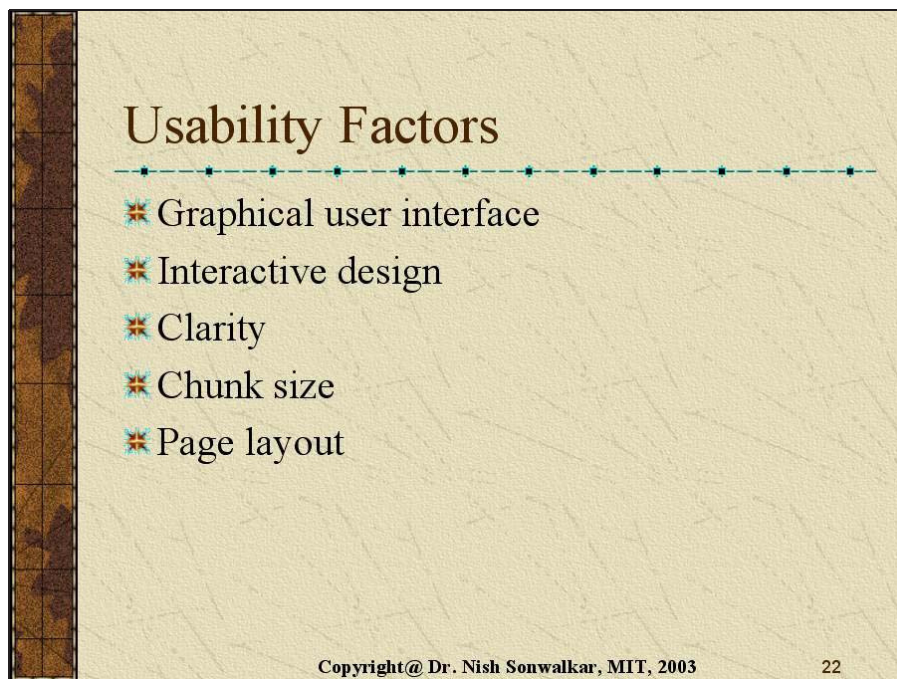
Figure 22

THE TECHNOLOGY INFRASTRUCTURE FACTORS

The technology infrastructure in essential for the success of the course. These considerations include the network bandwidth, target systems, such as, mac, pc and unix operating systems, server capacity, browsers, IE, Netscape, AOL, and database backend, SQL, Oracle etc. The information technology department sets standards for these technology standards.
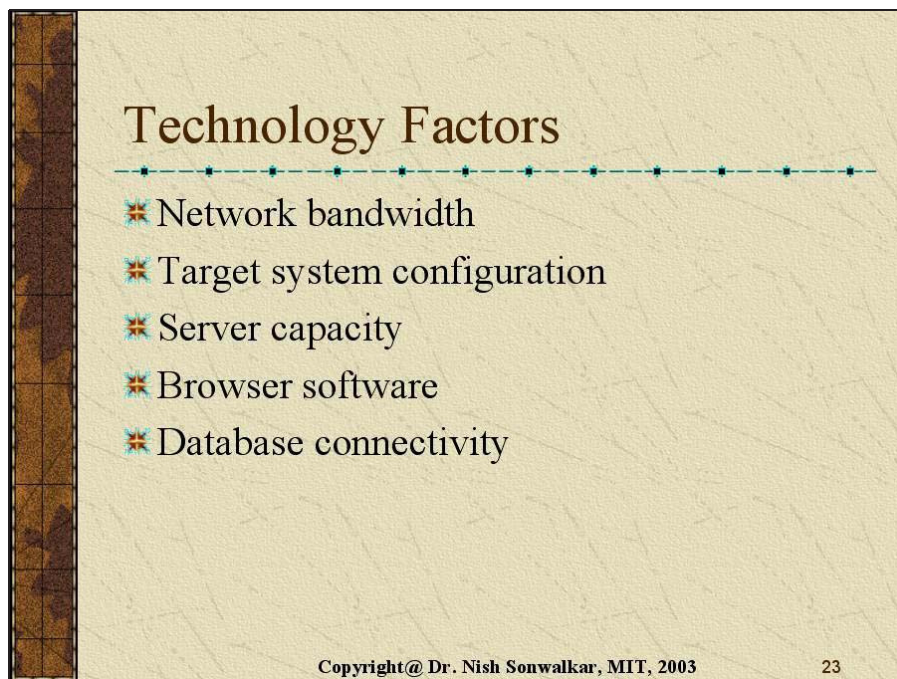
Figure 23

THE FIVE FACTORED SUMMATIVE SURVEY INSTRUMENT FOR MEASURING USER EXPERIENCE

A survey instruments is create with a Lickert scale of 0 to 4 for getting learners experience for the five factors described in the earlier figures. The survey instrument provides a summative score for the course in the range of 0-4.

Figure 5: Summative evaluation instrument for rating online courses

No.	Evaluation Factors	Absent	Poor	Average	Good	Excellent
1	**Content Factors** Quality Authenticity Validity Media Presentation Attribution	0	1	2	3	4
2	**Learning Factors** Concept Identification Pedagogical Styles Media Enhancements Interactivity Testing and Feedback Collaboration	0	1	2	3	4
3	**Delivery Support Factors** User Management Course Content Accessibility Reporting	0	1	2	3	4
4	**Usability Factors** Graphical User Interface Interactive Design Clarity Chunk Size Page Layout	0	1	2	3	4
5	**Technological Factors** Network Bandwidth Target System Configuration Server Capacity Browser Software Database Connectivity	0	1	2	3	4

Reference: Syllabus, January, 2002
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Figure 24

OVERALL PEDAGOGICAL RATING FOR ONLINE COURSES
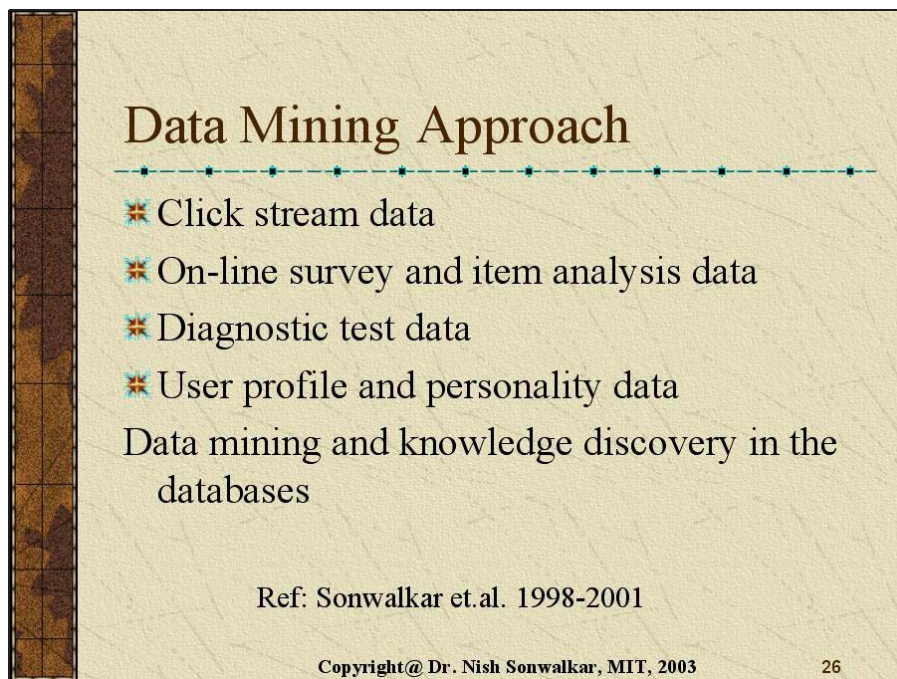
The PEI provides information about the how the course is designed and the summative instruments provides evaluation of the learners experience. The overall pedagogical experience can be defined as the multiplication of these two evaluations. The rating is in the 4.0 scale.

Figure 25

OPTIMIZING INDIVIDUAL PERFORMANCE; DATA-MINING

In order to understand and optimize the learners performance a data-mining approach is proposed. The data-mining approach includes click stream data, summative survey instruments, pretest-post test results, diagnostic performance evaluation data and user profile and personality data. Based on this data that is populated in a database with an entity relationship model, data mining approach allows discovery of patterns and associations.

Figure 26

ENTITY RELATIONSHIP MODEL: SCHEMATIC

A simple entity relationship model is proposed that describes relationship as: student as attributes that are defined by the personality data, the students evaluates the experience by a the summative instruments and student also has a performance.
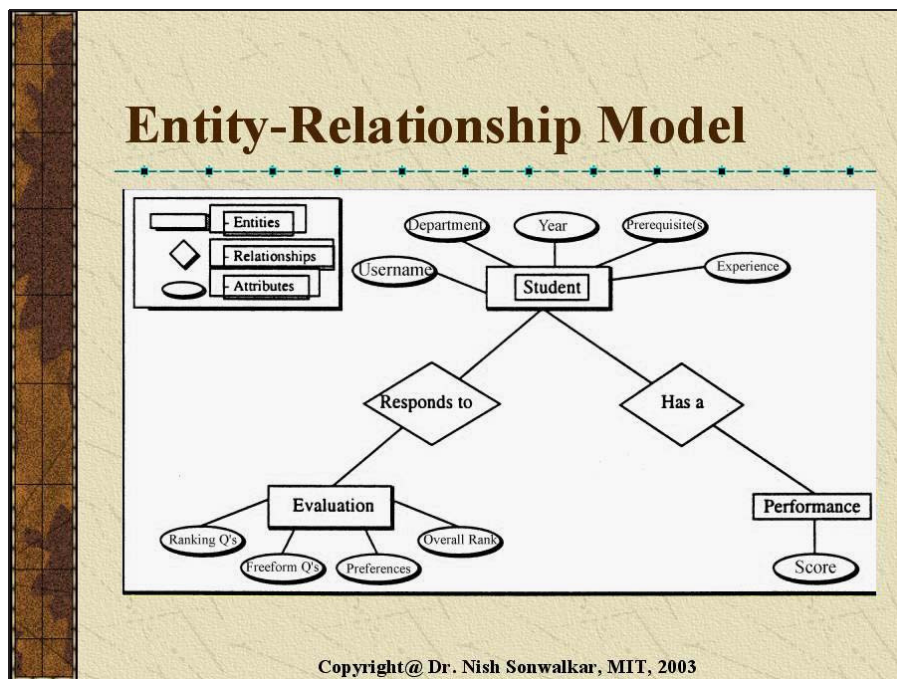
Figure 27

ENTITY RELATIONSHIP MODEL: RELATIONAL DATABASE SCHEMA

The entity relationship model given in the previous figure can be translated to a database model with primary key and foreign key model for the relational model between student attributes and student response to on-line course with the student performance. The proposed database model is described schematically with the relational element in this graph.
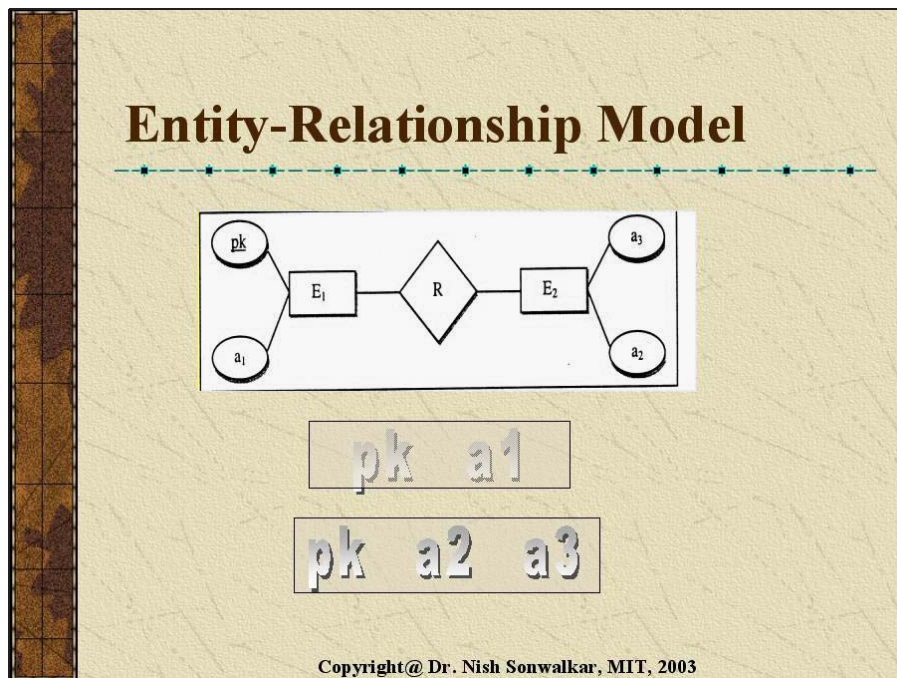
Figure 28

EXAMPLE CASE-STUDY: VIRTUAL ROTAMETER EXPERIMENT

The proposed data-mining model was applied at MIT on a course in the Chemical Engineering department. The course "Chemical Engineering Project Lab 10.26" was designed to provide a web-lab to calibrate rotameter (a devise that measures flow rate of fluids) based on the virtual water collected in a flask and a timer. The statistical analysis was conducted on the student who used the web-lab to understand the calibration process and those who used real laboratory (wet-lab) with actual instrument and water as a fluid used for calibrating rotameter. The results (published elsewhere, see reference 6), indicated for majority of the students the web-lab provided better learning then wet-lab. The experiment was conducted for two consecutive terms and data was analyzed using the data-mining approach to determine the association rules and decision tree based on the analysis of
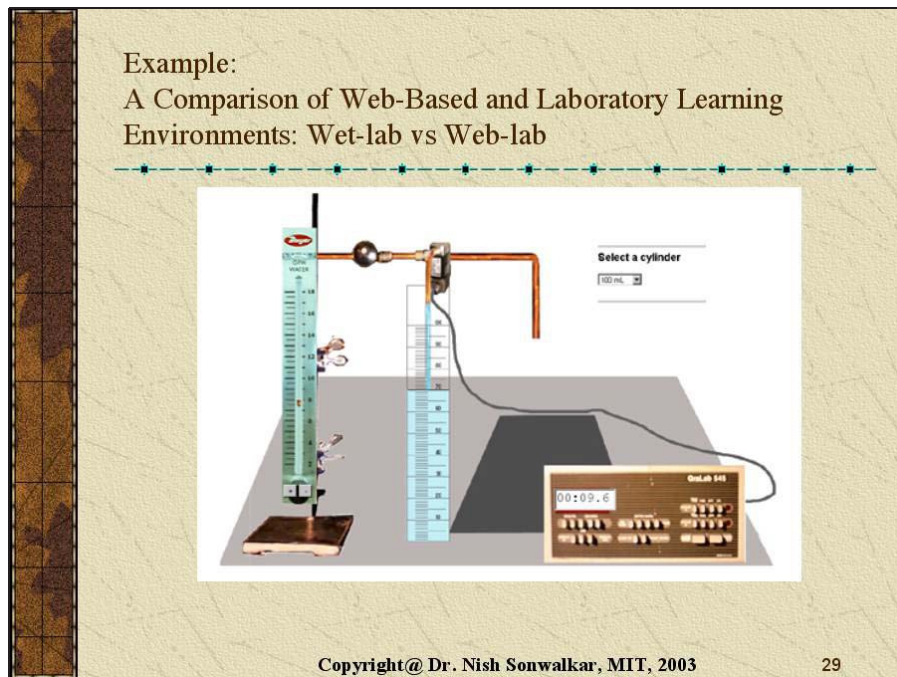
Figure 29

ASSOCIATION RULES

The data below indicates the association rules that were derived based on the data-mining analysis for the optimization of the learning experience using data-mining analysis. For example to rule 1 Indicates that the junior student had a good experience with the web-lab then wet-lab and there was 62% support for this association.

Association Rules

Rule	X	Y	Support	Confidence
1	Lab Environment = Hyperactive	Student Year = Junior	13	62%
2	Student Year = Junior	Lab Environment = Hyperactive	13	50%
3	Experience with Calibration = 'No' AND Student Performance = 'B'	Student Year = Junior AND Lab Environment = Hyperactive	8	29%
4	Experience with Calibration = 'No' AND Lab Environment = Actual	Student Year = Junior AND Student Performance = 'B'	6	43%
5	Experience with Calibration = 'No' AND Lab Environment = Hyperactive	Student Year = Junior AND Student Performance = 'B'	8	44%
6	Experience with Calibration = 'No' AND Lab Environment = Hyperactive	Student Year = Senior AND Student Performance = 'B'	5	28%

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Figure 30

66

THE DECISION TREE ANALYSIS

The data-mining analysis was also used to derive the decision tree. The tree indicated how various parameters have an impact on the performance of the students. Decision Tree for Determination of Student Performance with Student Year, Preference for Lab Environment, Experience with Rotameter Calibration, and Supposed Ease of Use as Categories in shown in this figure. Regardless of the year of the student, the past experience with calibration of a Rotameter, the choice of web lab, and the notion that the use of the web lab would facilitate the use of the actual lab, the most likely score is a B, i.e., the student consistently performed better on web-lab environment then wet-lab environment. The only case in which this does not hold is for third-year undergraduates who were undecided about their preferred choice of lab.
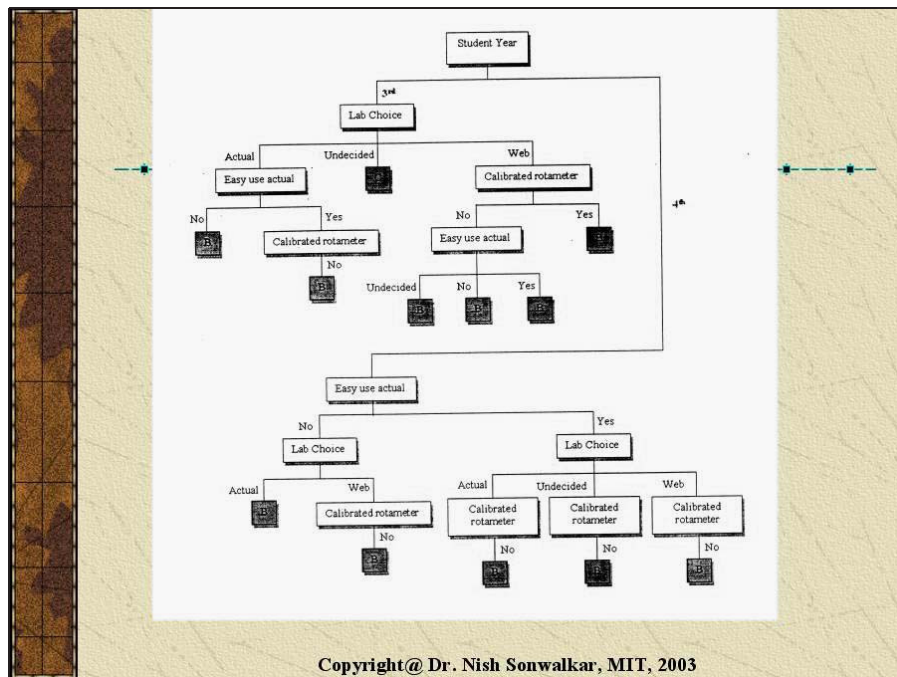
Figure 31

MAXIMIZING INDIVIDUAL LEARNING PERFORMANCE: THE ADAPTIVE LEARNING CYCLE

Therefore, utilizing the adaptive learning technology and data-mining approach for optimizing the performance it is possible to control the quality of the learning experience to maximize individual performance. The learning cycle approach depicts utilization of learning with adaptive technology leading to an evaluation of the learning strategy that givens the best performance results and providing remediation and guidance for the revision at the end of each cycle to continuously improve the performance outcome.
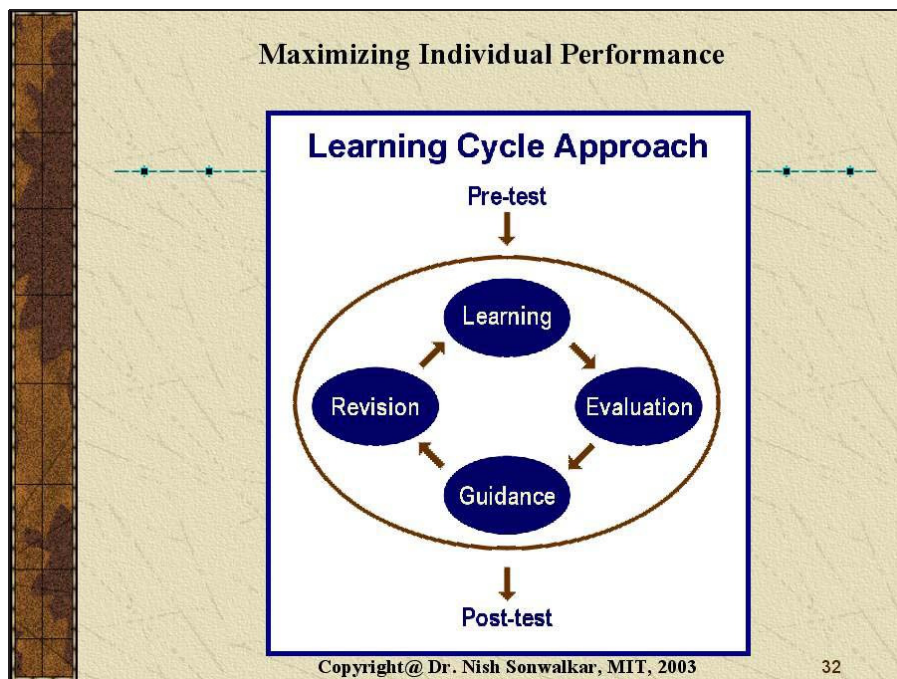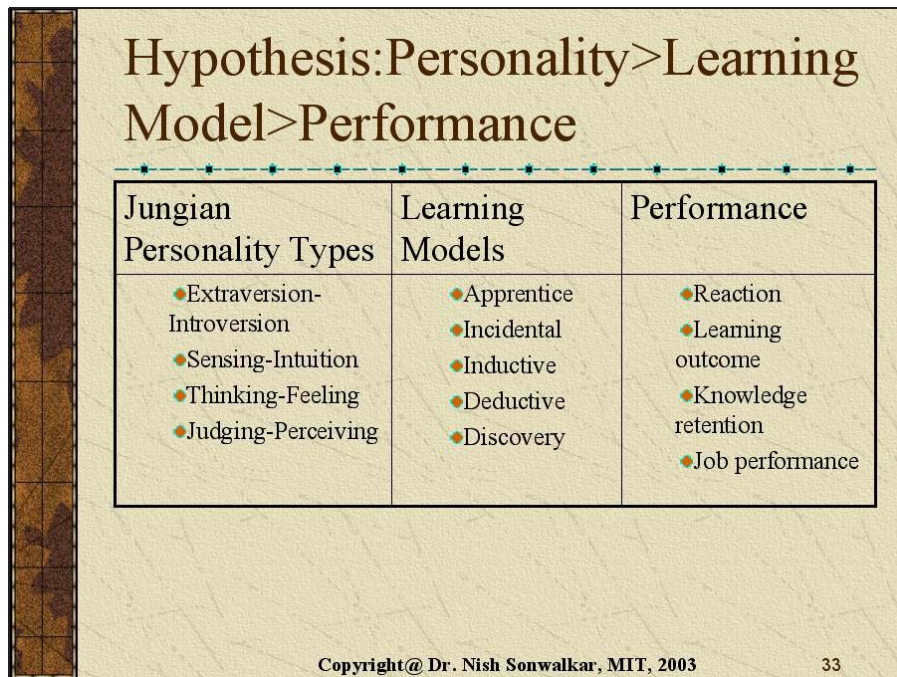
Figure 32

PROPOSED HYPOTHESIS FOR LARGE SCALE EXPERIMENT

The proposed hypothesis is to conduct a large scale statistical experiment to find correlations between the personality type, preferred learning model and the performance optimization. It is possible to populate large scale data on a diverse population and to use the data-mining approach to find the hidden associations that are strongly supported by the data and to use these association to provide a decision tree for extremely efficient and optimized learning/training paradigm for the optimum results in the shortest training/learning time.

Figure 33

CONCLUSIONS

The assessment of on-line education is a multi-dimensional problem

The three dimensions of on-line learning are: Media, Models and Interactivity.

The pedagogical effectiveness index (PEI) can measure the effectiveness of on-line course.

Summative evaluation can indicate the effectiveness of a course based on learners experience.

The overall pedagogical rating of the course depends on both the course effectiveness and learners rating of the course

A systematic approach to assess online instruction is needed to determine if correlations exists intended learning variables

An experiment is proposed to evaluate effect of the learner profile and learning model on learning effectiveness and performance improvements

Selected References:

Sonwalkar, N.,"Demystifying Learning Technology Standards-I", Syllabus, pp. 26-29, March 2002

Sonwalkar, N., "A New Methodology for Evaluation: The Pedagogical Rating of Online Courses" Syllabus, pp. 18-21 Jan., 2002

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Sonwalkar, N., "Changing the Interface of Education with Revolutionary Learning Technologies" published as the Cover Story of Syllabus, pp. 10-13, Nov. 2001.

Sonwalkar, N. "Assessing Virtual Environments for Learning: A Data mining Approach" submitted to the proceedings of Naval Postgraduate School's conference on Assessing Quality of On-line Education, 23-25, October, Monterey CA, 2001.

Burrell, B., Wiggins, R.J.N., Sonwalkar, N., Kutney, M.C., Dalzell, W. and Colton, C.K., "A Comparison of Web-based and Laboratory Learning Environments," Proceedings of the American Society of Engineering Education Annual Conference, 2000

B. McHenry and N. Sonwalkar "RIPE: Rapid Instruction Production Environment, ALN Magazine, Vol2, October 1998. (http://www.aln.org/alnweb/magazine/vol2_issue2/tools_techno.htm).

Conclusions

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- The three dimensions of on-line learning are: Media, Models and Interactivity.
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Figure 34

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Figure 35

Lessons Learned From the Program in Course Redesign

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LESSONS LEARNED FROM THE PROGRAM IN COURSE REDESIGN

Today using information technology has become an integral part of the life of colleges and universities across the United States to provide access for new students and in the teaching and learning mission. Most institutions, however, are finding the use of technology has become a costly addition as they have bolted it on to the traditional, class room based method of instruction. Thus information technology has added to the problem of rising costs in higher education. In addition, some research has shown that the use of information technology produces learning outcomes that are only as good as those in more traditional classes, rather than improving the quality of the learning experience; these findings are sometimes called the "no significant difference" phenomenon.

Managed by the Center for Academic Transformation at Rensselaer Polytechnic Institute and funded by a grant from the Pew Charitable Trusts, the Program in Course Redesign is designed to address these problems of the growing cost of information technology and the need to improve the quality of learning simultaneously. This talk is an overview of this program including a brief review of the process, the institutions involved and the lessons learned.
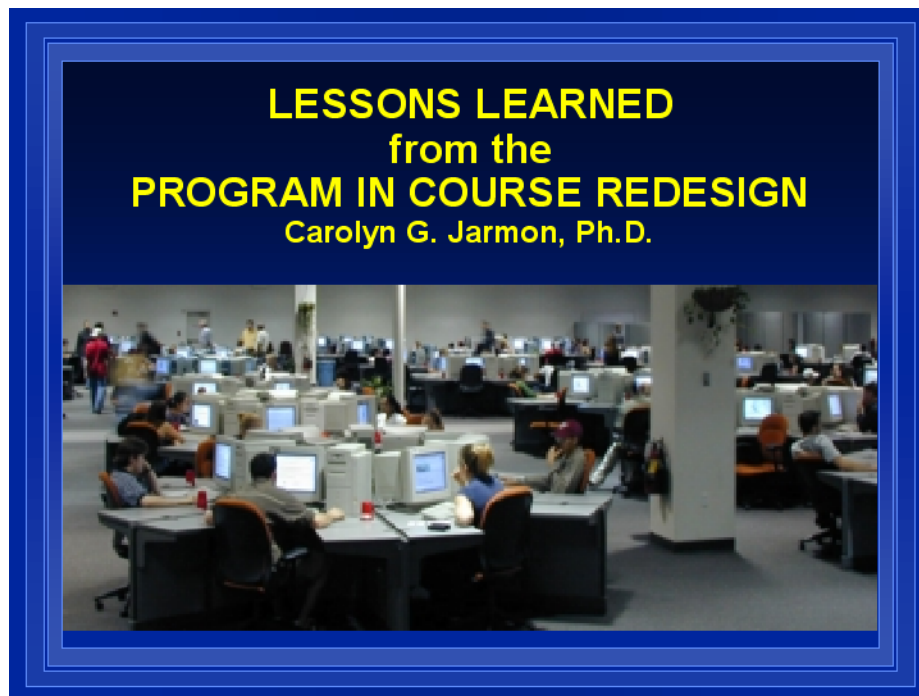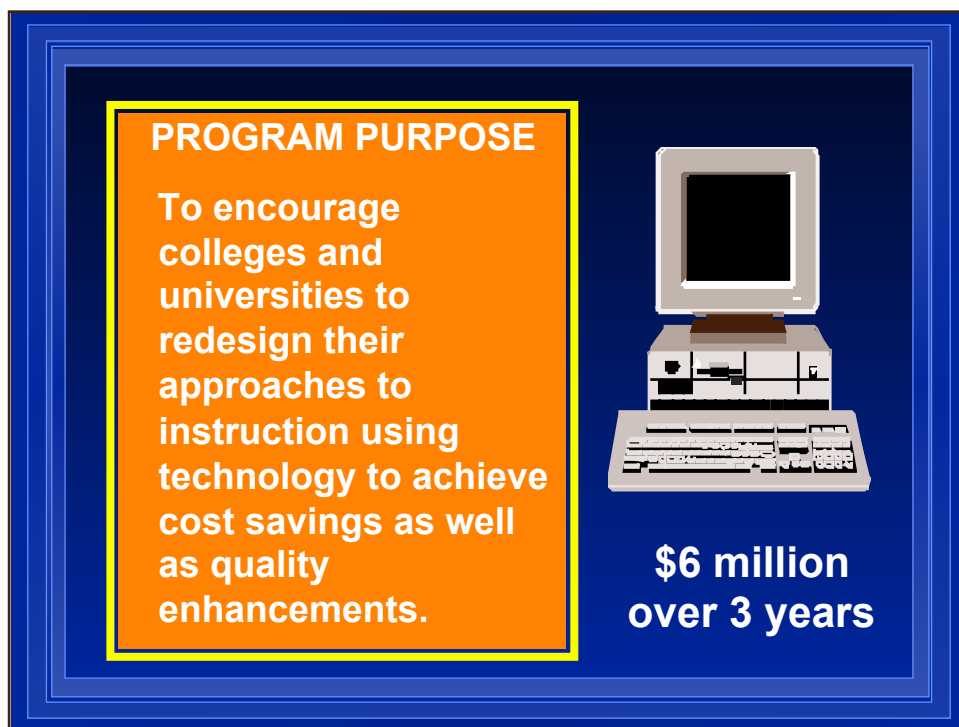
Figure 1

PROGRAM PURPOSE

This project is designed to address the three major problems facing higher education today: Access, Cost and Quality. As noted previously, many already believe that it is possible to increase access to higher education using information technology. However, there are many who also believe that using information technology to increase quality of student learning necessarily also increases cost.
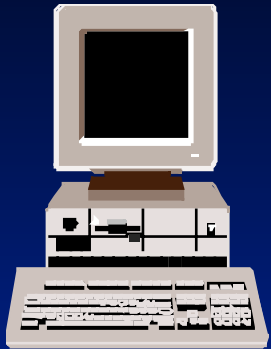
Although much has been written about whether or not it is possible to both control costs as well as improve the quality of student learning, there have been no demonstration projects that actually put these hypotheses to test. The Program on Course Redesign was established to move promise to practice. The overarching goal is to encourage colleges and universities to redesign their approaches to instruction using technology to achieve cost savings as well as quality enhancements. Chosen in a national competition including hundreds of applications, the 30 institutions each received $200,000 awarded in three rounds of ten schools.

Every project includes a rigorous evaluation plan focused on learning outcomes measured by student achievement. External national experts provided guidance to the project teams and review of the final plans to ensure that the results are both valid and reliable. Specific results are reported later.

Figure 2

PROGRAM OBJECTIVES

The program focuses on large enrollment, introductory courses because these courses reach large numbers of students at all institutions across the United States, use a more or less standardized curriculum and are a prime area of ineffective teaching. In many institutions, these courses are primarily taught by large numbers of adjuncts. These courses influence future majors and are feeders to a number of other disciplines. Finally large introductory courses absorb large amounts of resources. At the University of Wisconsin-Madison, for example, it costs over $1 million each year to teach Introductory Chemistry because the enrollment approaches 4100 students. In addition, at some institutions, these courses have large rates of drop-failure-withdrawal (DWF) and students have poor performance in downstream courses. Furthermore, many large enrollment courses are taught in multiple sections that experience significant course drift, meaning that some instructors cover all the material planned for the course, while others do not. Thus students move on to the next course with very inconsistent preparation.

The Program in Course Redesign is organized to provide a systematic approach to redesign so that other institutions might model this process and to provide mechanisms to share the information and conclusions drawn across the 30 projects. Thus interested institutions have multiple successful models that show better methods for students to learn, while controlling costs using information technology. The Center for Academic Transformation also provides opportunities for project partners to share their findings with other members of the higher education community.

Figure 3

ROUND I INSTITUTUIONS

The next three figures give an overview of the kinds of institutions that are involved in each of the three competitive rounds. The first group, shown above, includes one community college and some state institutions. Most are research universities with a large quantity of resources and a generally higher state of readiness to engage in course redesign.

All 30 institutions in the Program were trying to solve some problem that had an important impact on student performance at their campus. Among these problems addressed by the projects are high DFW rates, difficulty getting qualified adjuncts, long waiting lists for particular courses that are important for graduation, and inconsistencies of preparation of courses leading to multiple majors. As institutions were examining data collected about the top twenty-five, highest enrolled courses, they were able to identify the key problems affecting students in these large enrollment courses on their campus.

ROUND I INSTITUTIONS

- IUPUI (Sociology)
- Penn State (Statistics)
- Rio Salado College (College Algebra)
- SUNY at Buffalo (Computer Literacy)
- U of Central Florida (American Government)
- U of Colorado-Boulder (Astronomy)
- U of Illinois-Urbana Champaign (Statistics)
- U of Southern Maine (Psychology)
- U of Wisconsin-Madison (Chemistry)
- Virginia Tech (Linear Algebra)
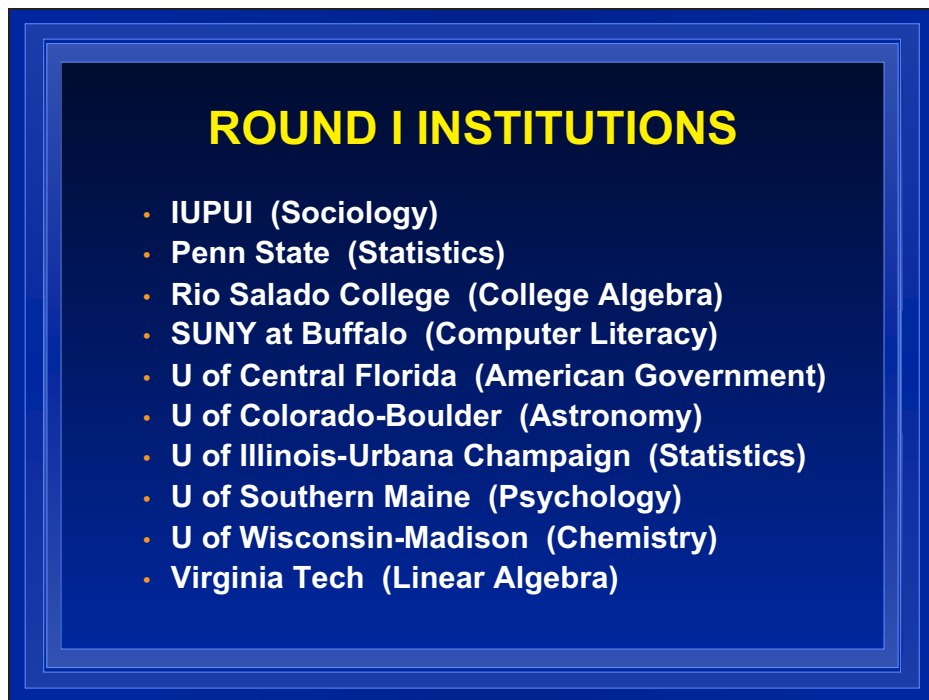
Figure 4

ROUND II INSTITUTIONS

These institutions are the ones selected in second round of competition in the Program on Course Redesign. Here, there are a large community college and two private institutions. Again there are also a large number of research universities who have a higher level of readiness and thus, are better prepared to do the kinds of large scale redesigns represented by this program. There is a good mixture of academic disciplines including Psychology and Spanish along with the quantitative and science areas.

ROUND II INSTITUTIONS

- Cal Poly Pomona (Psychology)
- Carnegie Mellon University (Statistics)
- Fairfield University (Biology)
- Riverside Community College (Math)
- The University of Alabama (Math)
- University of Dayton (Psychology)
- University of Idaho (Math)
- The University of Iowa (Chemistry)
- University of Massachusetts (Biology)
- University of Tennessee (Spanish)
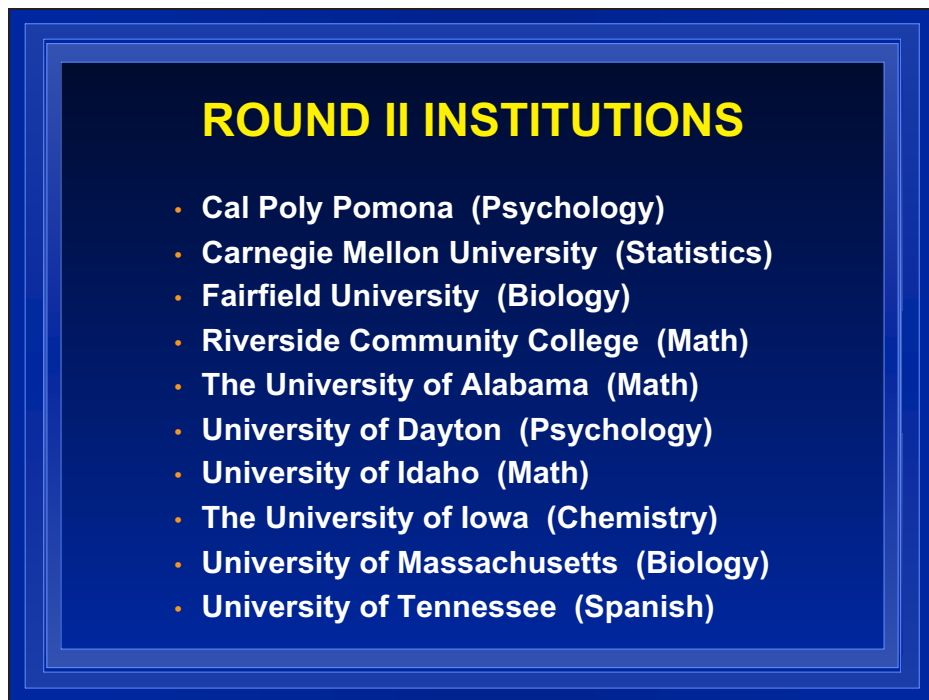
Figure 5

ROUND III INSTITUTIONS

The final group of ten schools includes the third community college, Tallahassee Community College, as well as private and state colleges. Again there is a predominance of research universities that have the higher level of readiness to participate in such a large scale initiative. This group of ten courses also includes a good representation of humanities subjects such as English Composition, World Literature, Spanish and the Fine Arts. Over the range of the thirty projects, the schools have tackled a variety of academic disciplines with a variety of models of redesign.

ROUND III INSTITUTIONS

- **Brigham Young University (English Composition)**
- **Drexel University (Computer Programming)**
- **Florida Gulf Coast University (Fine Arts)**
- **Iowa State University (Discrete Math)**
- **Northern Arizona University   (College Algebra)**
- **Ohio State University (Statistics)**
- **Portland State University (Introductory Spanish)**
- **Tallahassee Community College (English Comp)**
- **University of New Mexico (Psychology)**
- **University of Southern Mississippi (World Lit)**

Figure 6

GRANT PROJECTS BY DISCIPLINE

Among the 30 projects are a range of academic fields taught as introductory courses. These projects include math and other quantitative disciplines, humanities courses, social science and science courses. The benefit of this variety of academic fields is that they demonstrate that the approaches included in these redesign projects are effective for multiple academic areas, rather than just quantitative courses or science courses, as some would suggest. In addition, by tackling the various academic areas, the participating institutions were able to learn from each other and to compare what worked and what did not in the different fields.
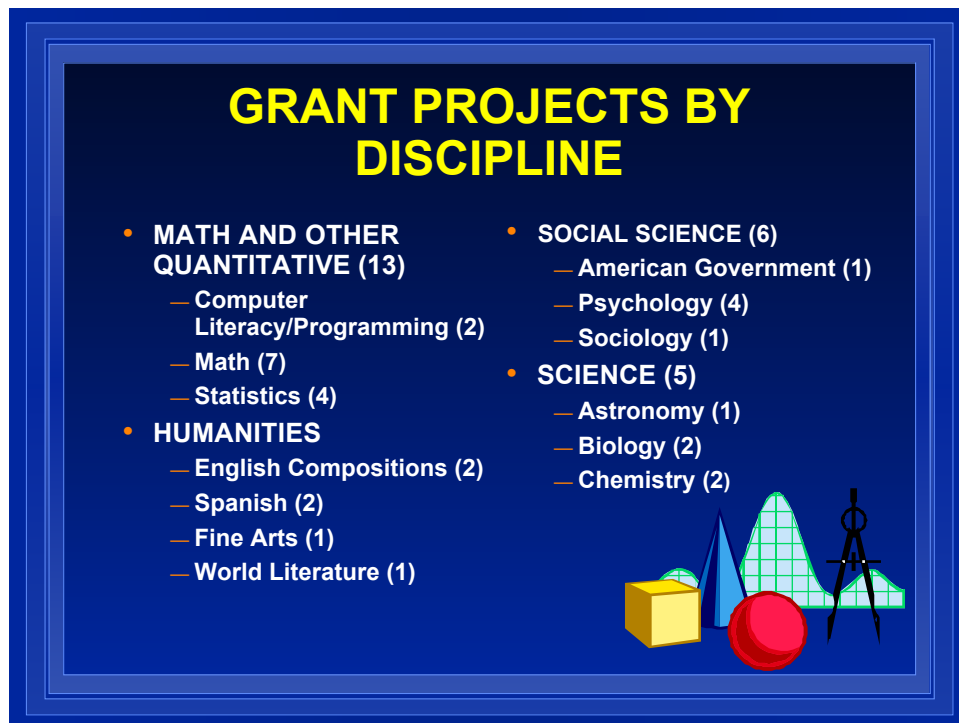
Figure 7

CLEAR PROCESS FOR REDESIGN

Key to effective course redesign is a process that prepares institutions to move systematically and leads to the ability to compare the cost per student before in the traditional course and the cost per student in the redesigned course. Each institution addressed two sets of criteria designed to assess their readiness to participate in such a large effort. The Institutional Readiness Criteria focus on the institution's strategic intent, personnel infrastructure as well as the ability of the institution to support a large scale redesign effort. The Course Readiness Criteria help an institution select a targeted course and examine the preparedness of faculty, students, and staff who will be involved. Subsequently the process involves a pedagogical and time analysis of what is currently done in the course and what options are available to improve student learning and reduce the labor intensity involved. The redesign team then carefully redesigns using the power of the information technology and crafts a doable plan. The full process and supporting tools are available on the Center's website for use by anyone who is interested.

Members of the Center for Academic Transformation provided extensive support in the planning, implementation and evaluation stages. This support was particularly important as none of the institutions had previously attempted such a redesign with such large numbers of students successfully. The support included both consultation and guidance regarding successful techniques and options when a participating institution hit a snag or problem.

Clear Process for Redesign

- Step #1 – Evaluate Institutional Readiness
- Step #2 – Select the course or courses using Course Readiness criteria
- Step #3 – Determine the specific tasks associated with offering the course.
- Step #4 – Determine all personnel costs for this course expressed as an hourly rate.
- Step #5 – Determine each person's time spent on each task.
- Step #6 – Calculation the total instructional costs for the course.
- Step #7 – Redesign the course by task and recalculate costs.

Figure 8

LARGE NUMBERS OF STUDENTS

The figure above shows the large numbers of students that are involved in the Program on Course Redesign. The students studying in the 30 courses totals over 50,000 in one year. As noted previously, the goal of this program was to demonstrate that information technology allows scaling of benefits successfully – greater student learning and lower costs of preparation and delivery. These high numbers indicate that it is possible to redesign large enrollment courses and to improve the learning environment for students.

Another criteria that was extremely important is sustainability. All of these redesigns will continue to have large numbers of students each year and the redesigns are structured so that they can be sustained with opportunities for continuous improvement and so that faculty can modify and improve the student experience.

LARGE NUMBERS OF STUDENTS

- Round I   20,585 students annually
- Round II   14,119 students annually
- Round III   18,724 students annually

ANNUAL TOTAL   53,428 Students
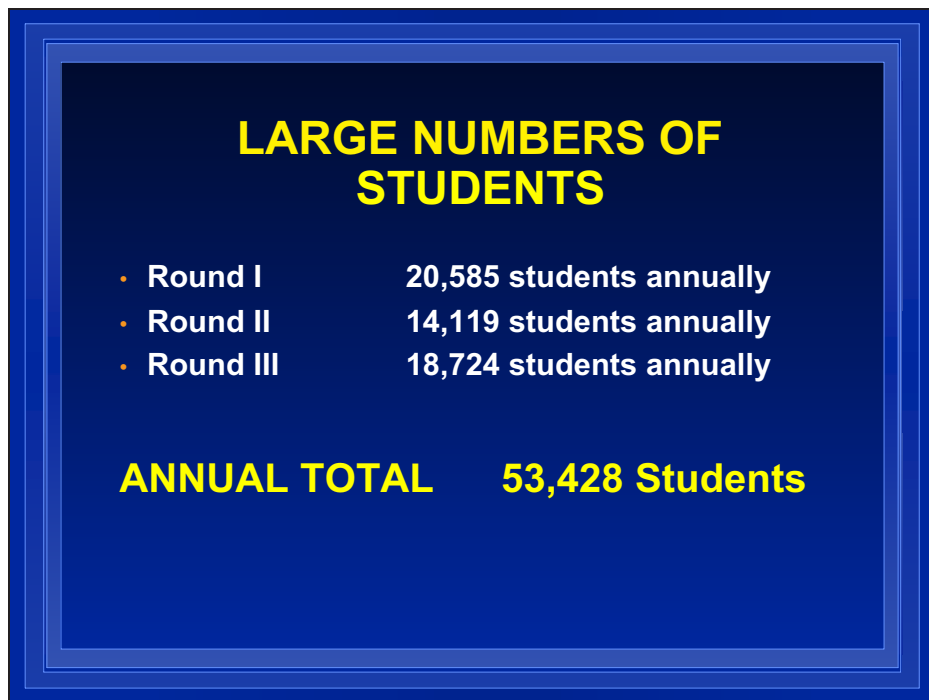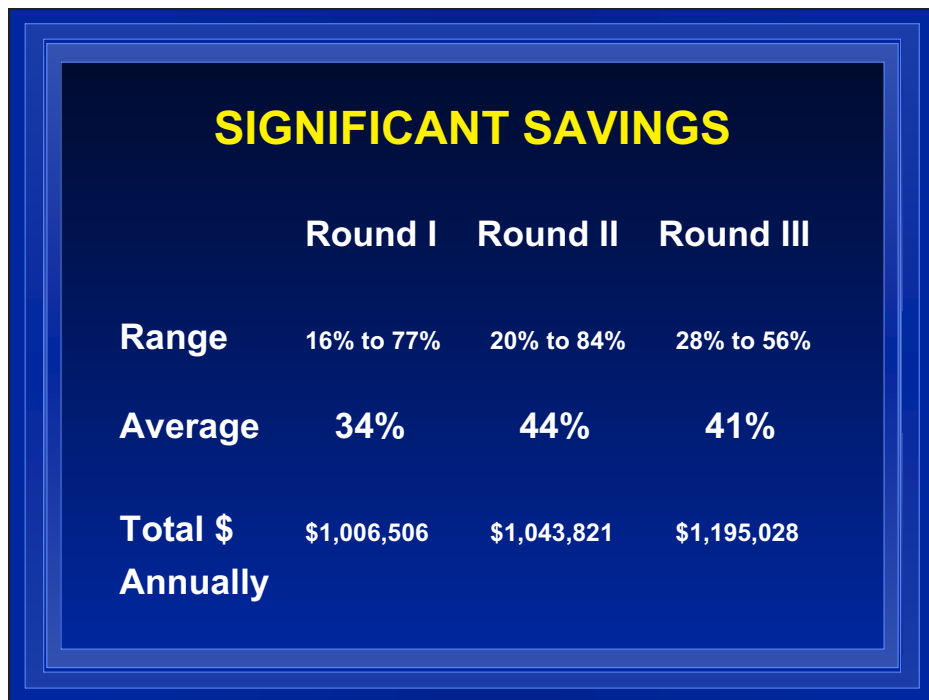
Figure 9

SIGNIFICANT SAVINGS

The major goal for this Program was to demonstrate that it is possible to redesign large enrollment introductory courses using information technology so that the quality of student learning increases (more on that later) and the cost of delivering that improved learning declines. All thirty institutions in the Program on Course Redesign reduced costs. The range is from 16% to 84%, totaling over $3.2 million dollars annually for 30 courses. The large enrollments in the courses is a key factor in the ability to save money as the pedagogical improvements that also reduce costs are scalable. Consequently the reduction in cost-per-student is significant when many students are involved.

Later, specific examples of methods used to reduce costs are included. These include reduction in faculty time by using the information technology to do the kinds of activities that are easily accomplished by the computer. In addition, some of the tasks needed by students do not require the expertise of faculty, but can be accomplished extremely well by other, less expensive personnel.

SIGNIFICANT SAVINGS

	Round I	Round II	Round III
Range	16% to 77%	20% to 84%	28% to 56%
Average	34%	44%	41%
Total $ Annually	$1,006,506	$1,043,821	$1,195,028

Figure 10

LESSONS LEARNED

       Turning to specific lessons learned from this process, the Program on Course Redesign has identified common characteristics of redesigns that when used, provide a better learning experience for students and reduce the cost of delivering the instruction. In addition, these common characteristics improve the quality measured by greater student learning. Further the various models established via the 30 different projects provide a range of labor saving activities that can be successfully used in concert with the improvement in pedagogical design for greater learning. Finally the Program has established that the characteristics that improve quality also reduce cost. Thus institutions can design learning environments that simultaneously accomplish these dual goals.

       The next several figures provide specifics regarding each of these lessons. There are examples of various specific pedagogical and labor savings changes that institutions can make to reduce costs and improve the quality of the student's learning experience.

LESSONS LEARNED

- Common characteristics of redesigns
- Increase in Quality
- Variety of labor saving options
- Variety of cost models all produce savings
- Cost and quality are related
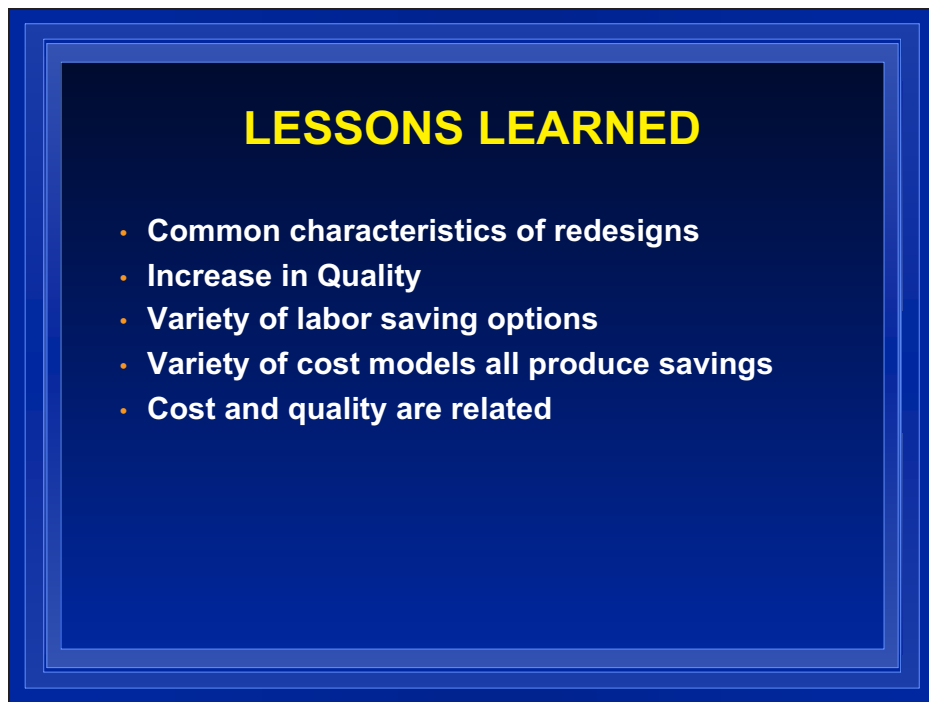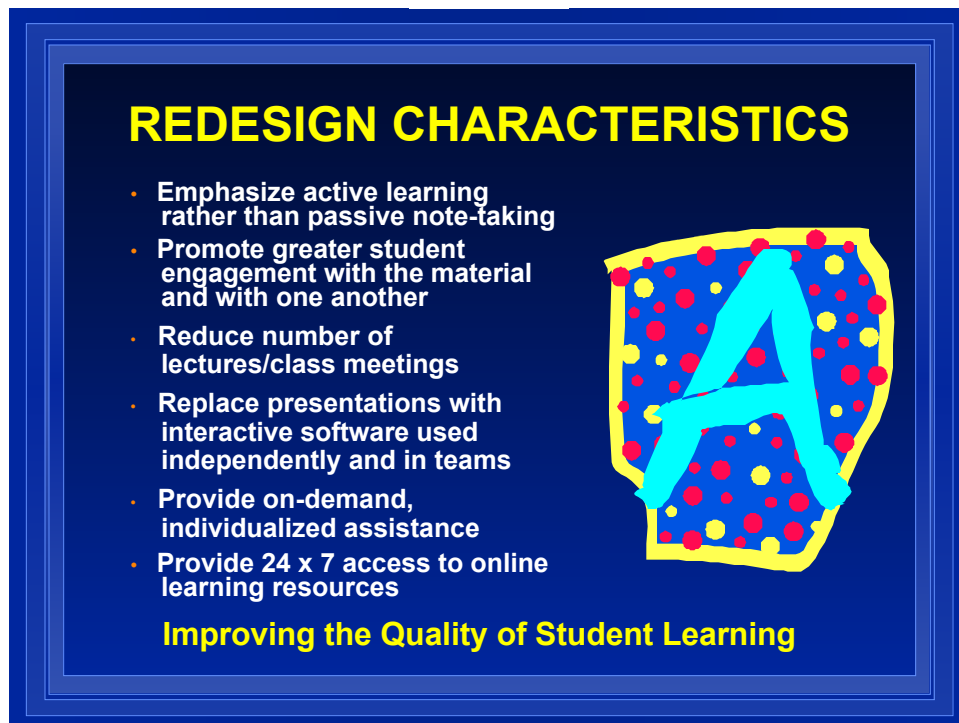
Figure 11

REDESIGN CHARACTERISTICS

The key idea found in all of the characteristics in this figure is active student engagement. Students need to be engaged both with the content of the course and with others participating in the learning experience. Those others include the instructor and the other students in the course. Active engagement means that students are no longer watching, but are participating. As one faculty member at Virginia Tech said, "Students learn math by doing math, not by watching math." That observation is not limited to math; it applies to all learning and these ideas demonstrate it.

In addition schools have included characteristics that increase the efficiency of learning for students. They can access learning materials 24/7 and receive the assistance they need when they need it, rather than during limited periods of time during the day. Students attend class for those learning activities that have been specifically considered as requiring face-to-face content; the redesigns move other activities online so that students who need to spend a lot of time on particular concepts can do so. Thus, the learning time is allocated by the student to those areas where they have difficulty learning and in those areas where the student already knows the information, they can move through more easily.

Figure 12

This second group of characteristics emphasizes recognition that some students need more practice and feedback than others. Here the use of automated grading with feedback permits students to work as many problems or practice a particular learning experience as many times as needed. In addition, after students have identified their own learning styles, it is possible for them to know more about how much practice and feedback they need and the ways that they learn best.

The use of differentiated personnel strategies permits students to receive greater assistance, at a lower cost. For example, at Virginia Tech in the Math Emporium, students receive individual help from faculty, graduate assistants and undergraduate assistants on demand when they have a problem. Also, they can join small groups with a tutor or work in pairs if that is desirable. Such strategies allow the response to come from a variety of personnel who assist at various levels and then are paid accordingly, rather than having a faculty member do it all.

Finally, these redesigns are breaking the credit-for-contact model. The redesign teams have carefully considered what kinds of activities need face-to-face activity and which are better learning experiences for students when done online. Rather than start with the idea that face-to-face is better, these teams have carefully considered the learning outcomes desired and then designed learning options to increase student success.

Figure 13

QUALITY OUTCOMES

The primary measure of quality in the Program for Course Redesign is increased student learning. Learning gains were evaluated by measures such as greater understanding of identified concepts, greater increases in learning using pre- and post-tests and greater mastery compared with the traditional course. Schools also measured course retention, comparing the number of students who dropped, failed or withdrew from the traditional course with the DFW rate in the redesigned course. One excellent way to reduce cost is to reduce the number of students who repeat the course.

Some institutions sampled student satisfaction via focus groups or student surveys. Where used, these provided information about how well the course was working and allowed for continuous improvement. Other institutions drew conclusions about the role of motivation and offered multiple approaches so that the student's overall motivation level was higher. After analyzing a two-term course sequence, one institution found they had a disproportionate amount of information in one term, and much less content to master in the other. They were able to remedy this problem.

Finally, the role of structure in redesigned courses is extremely important; these models are not self-paced. The design teams built in flexible structure with check-points or frequent assessments not only to allow students some flexibility to work more or less on a topic, depending upon their needs, but also to include frequent and useful evaluation, so that faculty and students know how well they are progressing. Then the faculty member can intervene if needed.
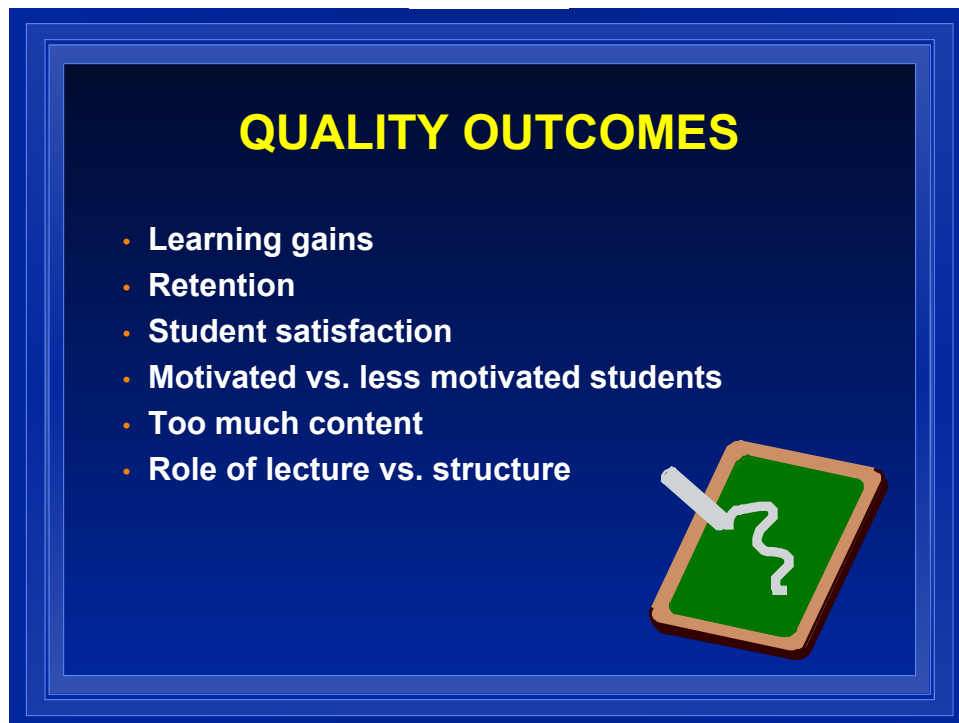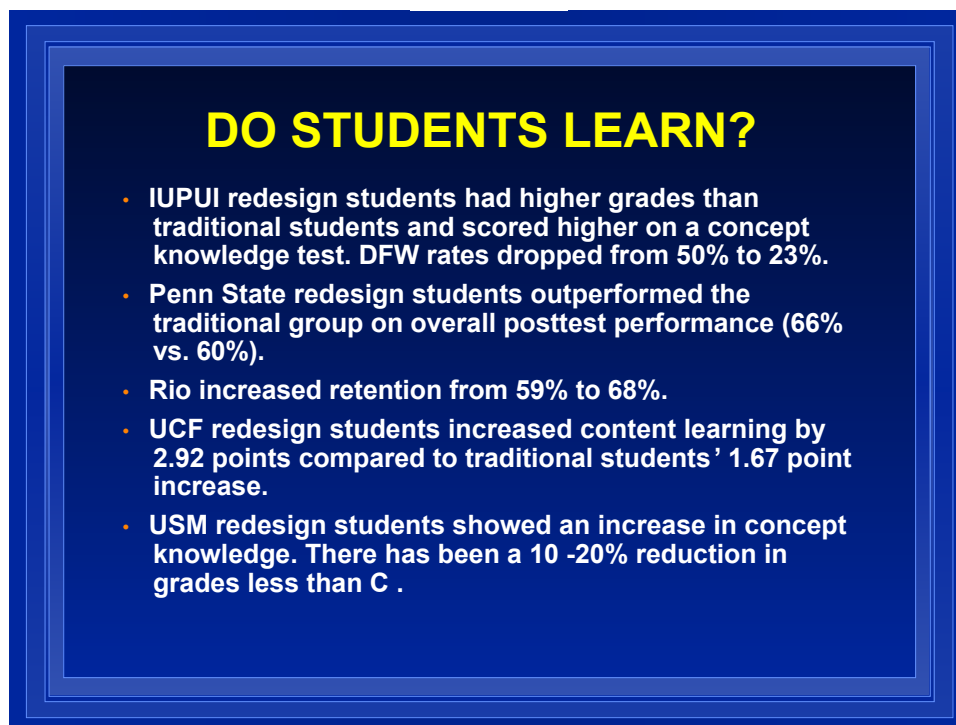
Figure 14

DO STUDENTS LEARN?

This figure provides several examples of improvement in quality of learning. Some demonstrate higher grades compared with students in traditional courses. Others show comparisons using pre- and post-test measures. Several also measured retention, the reduction in drop-failure-withdrawal rates. Given that all of these institutions have redesigned large enrollment, introductory courses, increasing retention is extremely important for continuing student success.

At the University of Tennessee, there were a large number of students who could not enroll in Spanish class that prepares them for the second year; this was a major bottleneck course. Students are now studying Spanish by shifting all grammar and writing to the online environment. The face-to-face class time has been reduced from four hours per week to two hours. In addition, the in-class time is spent almost exclusively on speaking Spanish. Instructors no longer work on grammar exercises; these are all done using an online workbook that is automatically graded. Based on data collected from students who have taken the traditional model, the students in the redesign are demonstrating greater proficiency in speaking and faculty are able to focus on the more complex tasks that need their attention. Students are using the workbook more effectively and the overall result is a significant decrease in cost of the course from $109 to $38 per student. In addition, with the new model, the University of Tennessee is able to accommodate over 500 more students each year.
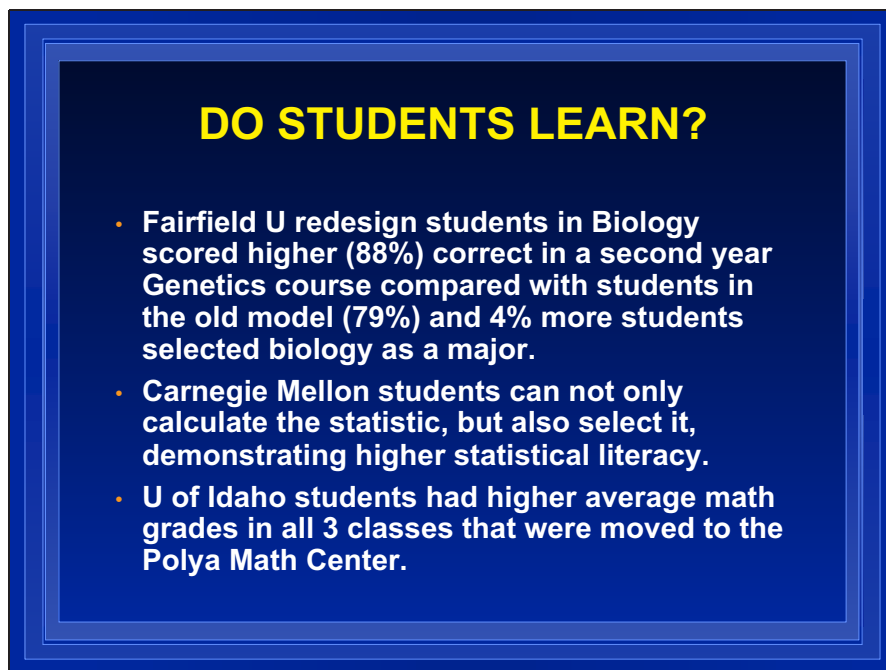
Figure 15

DO STUDENTS LEARN?

These are additional examples of the learning institutions found in their redesigned courses, compared with the traditional courses. At Fairfield University, the team have measured the learning in downstream or subsequent courses. They found that students retained content about genetics from the first year, as they entered the second year course. Thus, the faculty member no longer needs to spend significant time early in the course reviewing concepts covered in the first year; students are remembering the information.

At Carnegie Mellon University (CMU), faculty found that after the redesign of introductory statistics, the level of statistical literacy has increased dramatically. While their students have always been good at calculating the statistic, faculty were concerned that they were not as capable at selecting the statistic. The CMU redesign uses *SmartLab*, an automated intelligent tutoring system that monitors student's work as they go through lab exercises. Because *SmartLab* provides feedback to students when they go down an unproductive path and closely tracks and monitors a student's progress, it provides the equivalent of an individual tutor. The redesign is preparing students to more effectively utilize their statistical learning.

The University of Idaho modeled its redesign on the emporium model of Virginia Tech. Three math classes were redesigned and the average math class grades have improved. Students can work hard on topics they find difficult and spend less time on those that are easier for them. Students can get assistance when they need it; the outcome is extremely positive.
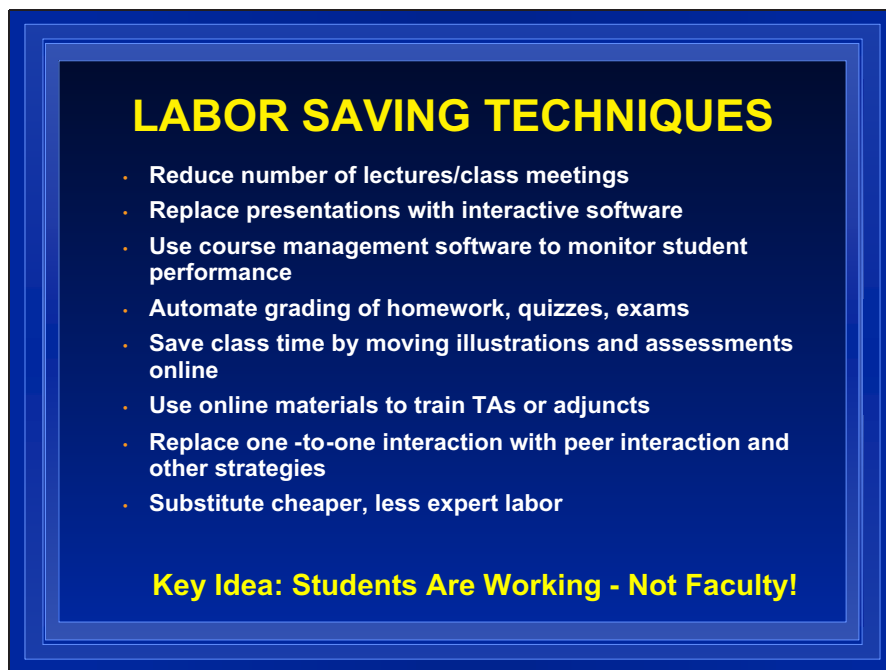
Figure 16

LABOR SAVINGS TECHNIQUES

This figure shows multiple ways to reduce time spent developing and delivering the course. The goal is to shift the work from the faculty, who already know the material, to the students who need to learn it. The tasks that can be accomplished well by the technology are moved. The automated grading of homework, quizzes and exams reduces the time for faculty or TAs and provides faster, more timely feedback for students. At the University of Iowa, Introductory Chemistry included over 16,000 items to be graded in one term; four graduate teaching assistants (TAs) were assigned fulltime to this task and could not evaluate every item. Now all items are graded by the technology; four TAs are available to accomplish other tasks.

The use of online materials for training both TAs and adjunct faculty has several benefits. The consistency of training is greater, as the resources are available every time someone new agrees to teach a course and when a TA or adjunct has a question. There is no concern about whether someone was told something important or whether they took good notes – all information is readily accessible. If there are changes, the resources can be easily modified and every one can be easily informed.

Key to effective redesign is the course management system (CMS). Monitoring and tracking are major tasks with large student numbers. Some schools incorporated an automated email system to assist with feedback to students and provide faculty with lists of those who have not completed benchmark tasks or other scheduled assessments. Faculty or others can follow up and provide the intervention, either personal or online, that students need. This helps academic development and motivation.

LABOR SAVING TECHNIQUES

- Reduce number of lectures/class meetings
- Replace presentations with interactive software
- Use course management software to monitor student performance
- Automate grading of homework, quizzes, exams
- Save class time by moving illustrations and assessments online
- Use online materials to train TAs or adjuncts
- Replace one -to-one interaction with peer interaction and other strategies
- Substitute cheaper, less expert labor

Key Idea: Students Are Working - Not Faculty!

Figure 17

REDESIGNMODELS

These models emerged from the thirty redesign projects. They were not established in the grant; they resulted as the projects developed their design responses to the problems they were facing on their own campuses. All models are scalable and, to a greater or lesser extent, all leverage information technology so that it accomplishes tasks it is most suited to do such as monitoring student progress and accomplishment; provide practice, review and feedback as much as an individual student needs; and evaluation of quantitative or short answer assignments. The models also include faculty and other people doing what they do best – providing individualized assessment and feedback when appropriate. All the models involve active learning, so that the student move to the center of the learning experience from the more passive orientation.

The model selected by a particular institution is related to the academic discipline of the course, the particular student audience and the preferences of the faculty involved.

Figure 18

WHAT DOES THIS HAVE TO DO…COSTS?

Coined by The Ohio State University, the term buffet model is appropriate because it effectively conveys the idea that students are drawing on an array of learning resources to achieve an established set of learning outcomes based on the student's individual learning style. Although faculty have always known that all students are not alike in their learning styles, capabilities or previous knowledge level, it has been difficulty to provide the range of learning resources and experiences needed for a truly individualized learning experience. Information technology can radically increase the options for students. It is no longer necessary to treat all students alike; institutions can provide more individualized and personalized learning experiences.

Figure 19

A BUFFET OF LEARNING OPPORTUNITIES

The five characteristics are part of the buffet model. First students can use one of several online instruments to identify their learning styles and the results can guide faculty in designing the array of high-quality, interactive resources. Students can establish individualized study plans given their preferences for learning and the resources that are linked to the established learning outcomes for the course. Built-in, continuous assessment provides the feedback students need to make progress or return to a topic and study further and the technology can monitor and track the student's activity. Finally the appropriate and varied kinds of human interaction can be planned and provided as needed.

The student becomes the focal point in the learning experience. The quality of the experiences increases and the costs decreases for both the institution and the student. The institution can staff as needed by students at a level appropriate to the need and the student can spend his or her valuable time studying effectively those topics that they have not yet mastered.

Figure 20

94

OHIO STATE UNIVERSITY

The next several figures focus on one example of the application of the buffet model. First it is important to understand the kinds of issues that Ohio State University (OSU) was facing in their introductory statistics class. This course is quite large and serves a variety of majors across the university. It had already undergone a redesign effort that led to increased costs and increased workload for faculty. There were many sections and the outcomes for students were extremely inconsistent. Students were not attentive and lectures were poorly attended. The DFW rates were too high – 20% of the students repeated the course each quarter. Further, faculty knew that some students successfully completed several modules, but did not finish the entire course on-time. Thus, each term they had to start over, but might again not reach a sufficient level of completion to earn a grade. In addition, the faculty knew that there were many different learning preferences and styles among the students enrolled.
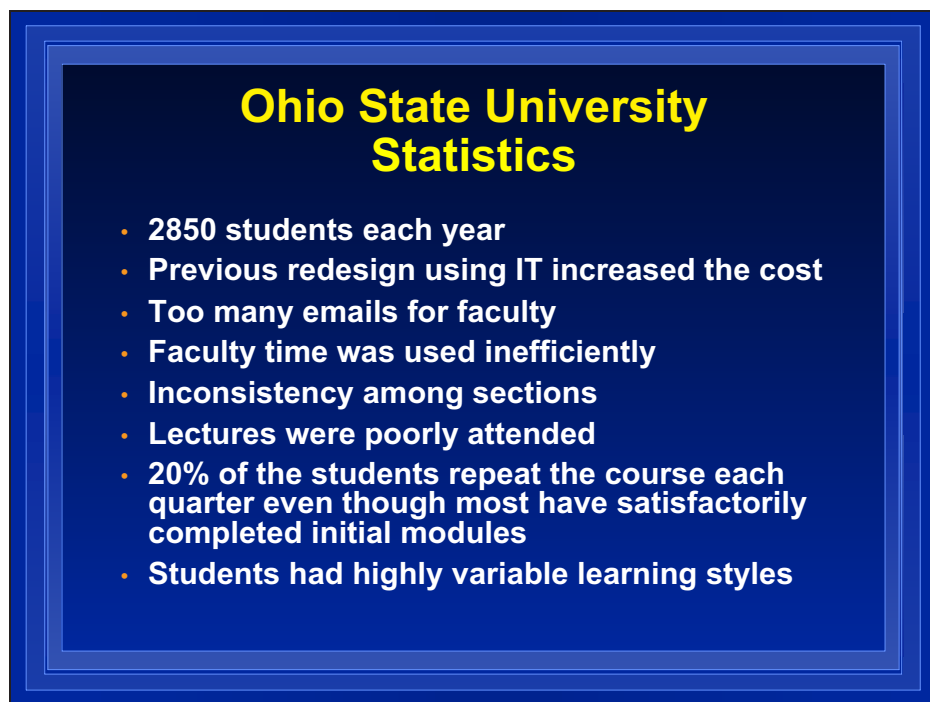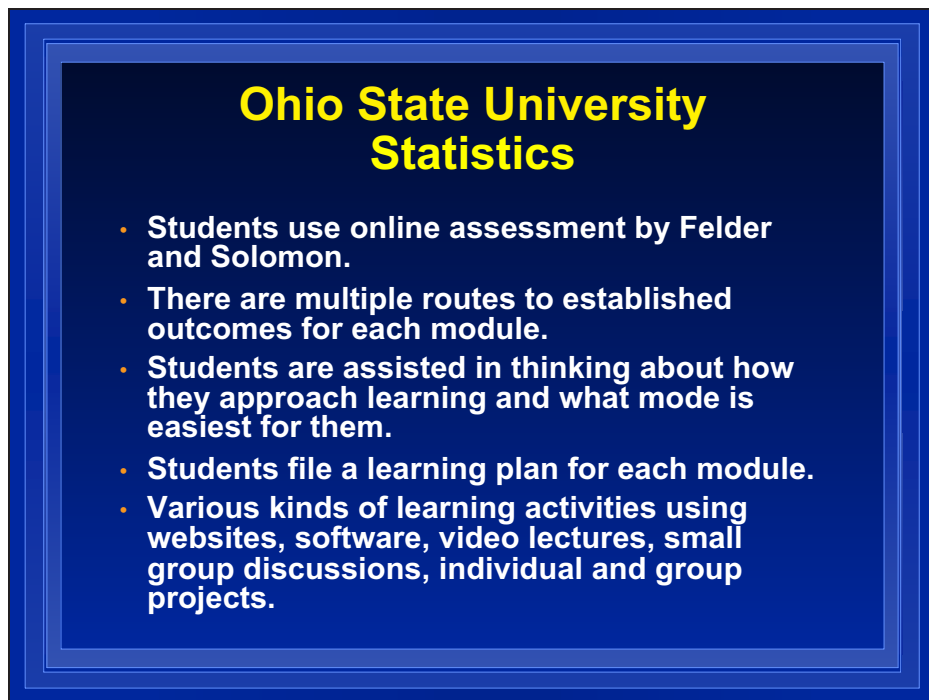
Figure 21

OHIO STATE UNIVERSITY STATISTICS

The Ohio State University (OSU) has developed a redesign project that uses these principles. OSU offers students a choice of interchangeable paths to learn each course objective. The buffet includes lectures, discovery laboratories, live and remote reviews, small group study sessions, videos, training modules, oral and written presentations, active large group problem solving, homework assignments (TA graded or self-graded), and individual and group projects. After an orientation to this new approach to learning, students assess their learning preferences and at the beginning of each module, enter into a contract in which they make choices among the options based on their understanding of their own style and preferences of learning. The contract provides students with a list of what needs to be accomplished with checkpoints and dates for completion. Based on their experience, students may make different choices in subsequent modules. Course software monitors their progress and provides management assistance for faculty.
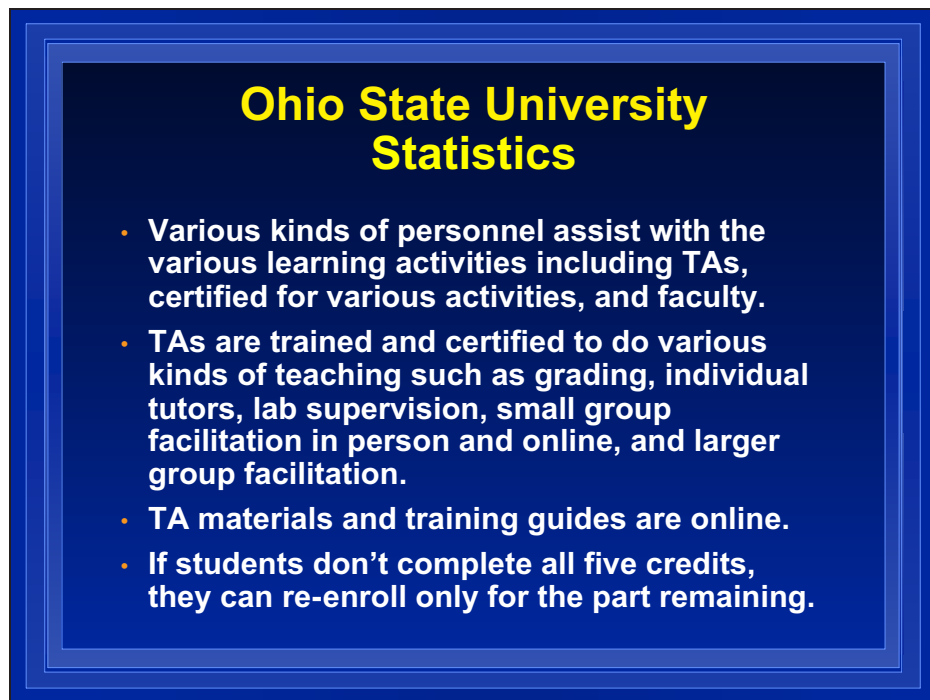
Figure 22

There are some additional benefits for OSU in this buffet strategy. Several kinds of personnel participate, providing greater interaction with students and assistance when they need it. Graduate teaching assistants (TAs) as assigned tasks in the array of experiences based on their certified level of competence. The training materials for the identified levels are online and TAs can review and practice prior to demonstrating their ability. As TAs become more skilled, they move from grading and working with individual students or small groups to responsibilities for larger face-to-face groups or monitoring online components. Thus, TA development is an integral part of the buffet and provides continued quality control.

OSU solved the dilemma of students who complete part of the five credits, but cannot finish the entire course in one term. Students who complete three or more segments earn credit for those segments and only re-enroll for the remaining segments in the next term. Thus, more students are ultimately successful, even though some may take longer than others to reach the level needed for success.

Figure 23

PROGRAM OUTCOMES

The Program in Course Redesign has achieved its major goals. The 30 projects have produced multiple models for course redesign and these are useful to the academic community.   The 30 projects have created a substantial body of practice and proof of concept that shows that these redesign models are scalable. All 30 projects saved money for their institutions and the amount saved is directly tied to the kinds of decisions that the redesign teams made. The Program has shown that it is possible to teach a return-on-investment strategy and that institutions can implement it. The 30 projects demonstrate that it is possible to improve the quality of the large enrollment courses and that the multiple models can be used in range of academic areas successfully. Finally the models provide an alternative to the multiple-section model, and all of the difficulties related to consistency that these have.   These represent the original goals and the Program has clearly demonstrated the successful proof of concept for others in higher education to use.
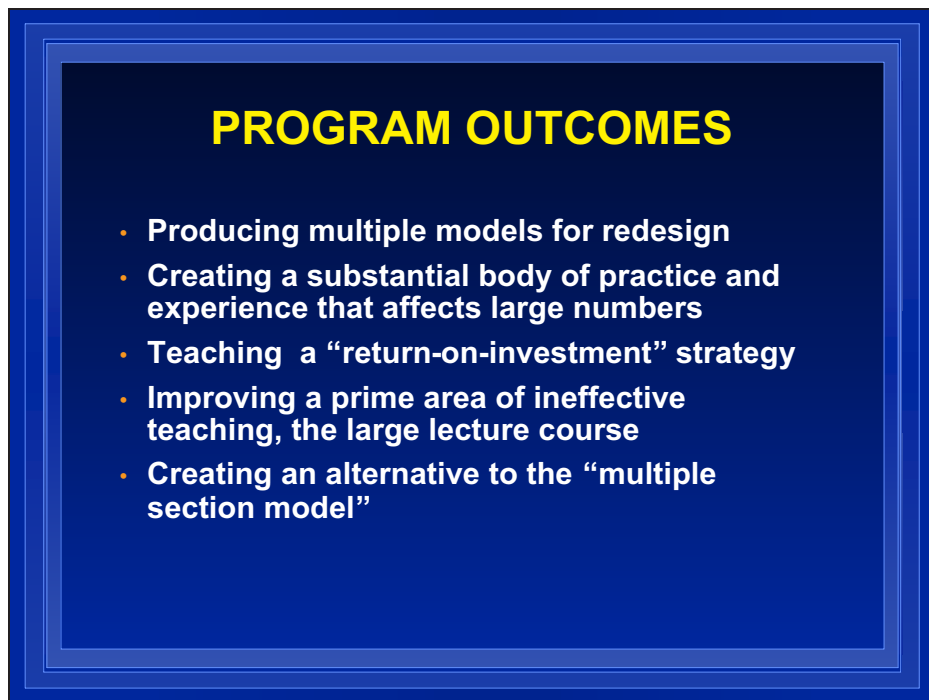
Figure 24

These thirty projects have provided a proof of concept of two ideas that were previously considered polar opposites. Most believed that if an institution used information technology to improve the quality of a course, then the cost would, of course, increase. This Program has demonstrated that it is possible to decrease the cost of offering the course, while enhancing student learning. However, there is further work to be done. While these 30 institutions have been successful, many others are not ready to undertake such a large-scale course redesign – how can they increase their readiness?

The buffet approach demonstrates it is possible to design learning environments that can be individualized for students, but we have only two projects among the 30 that have done so. There are undoubtedly more options available and what are the next steps to expanding this concept and applying it in other academic areas?

What kinds of models work best for what kinds of students and academic areas? Although there are some indicators of answers for these questions, greater study and research is needed.

Finally, more software options are needed. The market for software is expanding, but the opportunities are much wider than the market currently allows. How can software be designed to meet the needs of different kinds of students and how can faculty know what to use with different students? These are among the valuable research questions – and there are likely many more!

Research Questions

- How can we make sure institutions are ready for large scale redesigns?
- What are the next steps to expand the options for individualized learning environments?
- Which models work best for students with various learning styles and for particular academic areas?
- How can we improve the software options so that they meet the needs of students more effectively?

Figure 25

LESSONS LEARNED FROM THE PROGRAM IN COURSE REDESIGN

The Program in Course Redesign has a well organized and comprehensive website that is available to all who would like to explore these ideas further. Complete information about each of the thirty projects that make up this program is available on the Center's website: www.center.rpi.edu. Every reader can easily explore specific projects that are particularly useful to an individual institution by visiting this searchable site. In addition, each of the projects includes a contact person, whose name and email address are easily found on the website. Thus, should a particular project be relevant to a problem under consideration, be sure to consult the contact person at the institution that has investigated the academic area of interest. These contacts are willing and excited to talk with anyone who would like to ask questions or learn more about a particular one. Do not hesitate to contact Dr. Carolyn Jarmon or the project representatives for more information.

Figure 26

Lessons from a Resource for Learning across Disciplines – The Aerospace Digital Library

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LESSONS FROM A RESOURCE FOR LEARNING ACROSS DISCIPLINES – THE AEROSPACE DIGITAL LIBRARY

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Website for users: Aerospace Digital Library   http://www/adl.gatech.edu
Research on engineering education: http://www.ae.gatech.edu/~nkomerat/

To work at the leading edge of technology, the engineer must be able to absorb and integrate knowledge from many disciplines, and from all over the world. The metaphor of a digital library was used to develop a self-sustaining resource prototype and study such learning. Conceptual design provides perspective through a learner-centered gateway, which accepts users at any level. Sequential course material presents the discipline rigorously and logically, with Concept Engines cross-linking subject areas. User experience and lessons learned are discussed. Simple introductions, undergraduate-level content and guidance to related areas are the most popular resources for users worldwide. Resources built around discipline portals offer natural vehicles for collaborative linking of knowledge bases around the world.
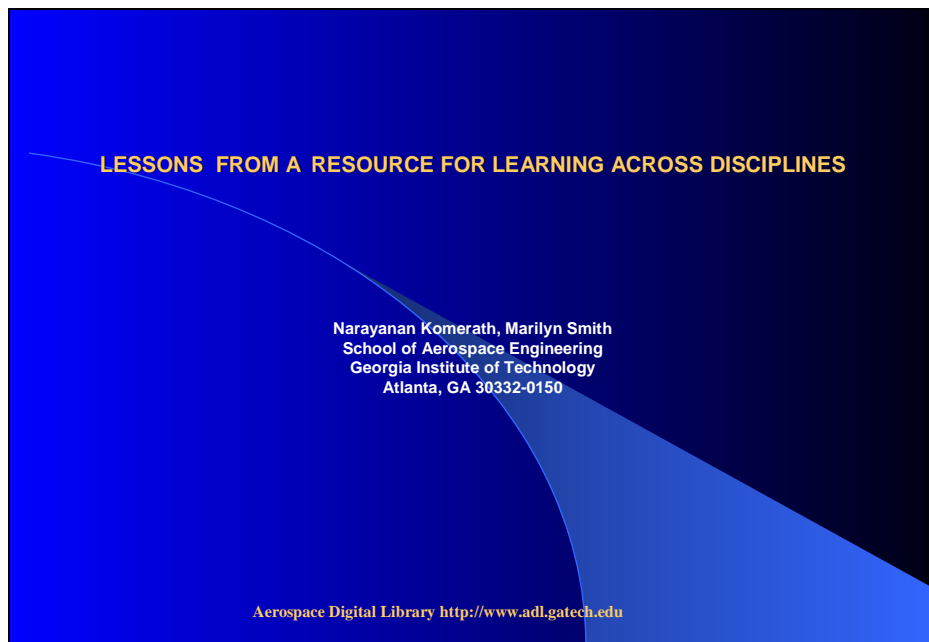
Figure 1

OUTLINE

Our aim is to develop an environment where aerospace engineers can integrate knowledge efficiently, bridging other disciplines as new knowledge is integrated into the knowledge base. We hope users from other disciplines will generate similar resources centered on their own disciplines. Here we list issues faced in developing such resources, then go on to describe our approach, experience with its growth, evolution and usage, the lessons learned, and guidance for the future.
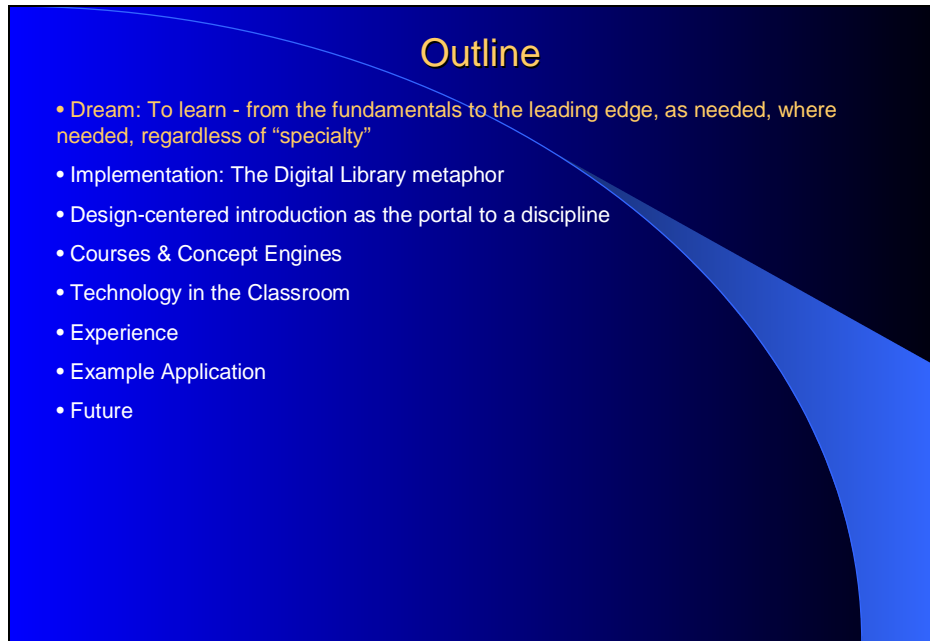
Figure 2

LEARN – FROM THE FUNDAMENTALS TO THE LEADING EDGE

In developing this resource, we have kept four different types of "customers", to be satisfied in the short term, shown in the figure. We know of current participation by the first 3 types, and hope to bring in the fourth type in the short term. In addition, we hope that the resource evolves into a "one-stop engineering resource" which provides guidance to the latest developments in many disciplines, while maintaining the ability to learn the basics and the evolution history. In addition, the resource should cater to learners of different styles, and even select and organize material and resources to suit individual preferences and needs.

Figure 3

THE DIGITAL LIBRARY METAPHOR

We used the "Digital Library", drawing upon the ten essays in Ref. 1. The "library" metaphor includes archival collections, indexing, peer review, interactivity, gatherings, guidance and exchange between learners - a metaphor for *the learning environment* as well as content. As a starting point for content development in cross-disciplinary learning, users need basic knowledge to decide where to seek data. Thus we aspire to provide guidance and linkage, and leave content development to specialists.

We have followed a bottom-up approach to system development. The initial critical mass of content was developed, based on available knowledge and hypotheses. As usage and users evolved, the lessons were used to refine the system and expand it. The picture shows aerospace engineering sophomores from Georgia Tech conducting a flight experiment on the NASA KC-135 Reduced Gravity flight laboratory in 1998 – a project which provided proof-of-concept for some of the cross-disciplinary learning hypotheses used in designing the knowledge resource.

Figure 4

IMPLEMENTATION USING THE "AEROSPACE DIGITAL LIBRARY"

The learning resource was developed by adding basic engineering course content to the unique strengths of the internet. The content of present courses represent our best efforts, evolved through decades of experience, to provide a concise, logical, systematic and in-depth treatment of what we believe the learner must learn. It is true that these courses were developed under various constraints which may be removed by applying technology. However, until better systems are proven, these courses remain the baseline for knowledge resources.

The structure of each course is linear and sequential, built up of distinct modules, or chapters, but each depending in some way on what was developed in prior modules. Using "Concept Modules", we link concepts and methods across courses. We also tie professional applications and resources to these Concept Modules, and provide links to the leading edge of research.

The Concept Modules with their links will keep evolving, and are the focal points for intellectual effort in developing this knowledge resource. As a starting point, the introductory lectures of each section in a course provides a rudimentary Concept Module, and provide the vehicles to link many types of resources.
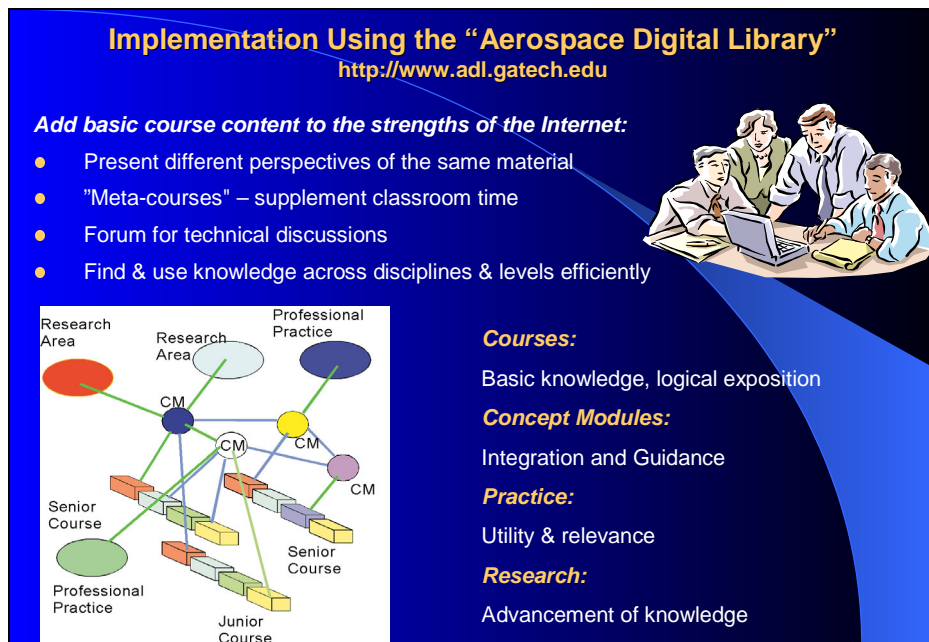
Figure 5

GATEWAY: DESIGN-CENTERED INTRODUCTION

The Internet opens up avenues for cross-disciplinary problem solving. In 1996 we used it to explain the diverse knowledge streams behind research projects. In 1997, an experiment in teaching first-term undergraduates demonstrated that the conceptual design of an airliner was an excellent focus to convey perspective on aerospace engineering (Ref.2). Conceptual design of a major system is an excellent integrator –when one realizes that *it generally uses basic laws and thumb-rules to make decisions, leaving details to advanced methods and iteration.* This makes it amenable and exhilarating to those who are yet to learn rationales for technological decisions. Seeing the areas of uncertainty helps learners understand the need for advanced theory and measurements that constitute much of the discipline.

Figure 6

APPROACH: THE RUNWAY ACROSS CANYONS

The approach used in the Design-Centered Introduction is analogous to building a runway across land fissured by canyons or crevasses. Students are not assumed to have the time or ability to go deep into each area before climbing out again for perspective and going into the next area. Instead, we bridge the gaps in knowledge through thumb-rules or shortcuts – while providing the student a glimpse into the depths and possibilities of each sub-discipline. For example, spreadsheets are used instead of integration in calculating, say, the trajectory of a space launch vehicle – knowing that first-semester students may not yet have taken integral calculus. Drag coefficients are given for performance calculations.

As the student's perspective and confidence build up, along with the experience of locating what they need on the internet and elsewhere, the speed of learning does indeed increase dramatically, within a matter of days. E-mail interaction with the instructor, and construction of a web page are enforced at the beginning to get students used to the idea of using the internet and of asking questions. The content of the e-mails quickly evolves from "when is the deadline" and "I can't get my web page to work" into technical decision-making questions indicating commendable depth of thought. What appears at first sight to be a compromise of academic rigor in fact enables a "takeoff" into a level where such rigor is enhanced.
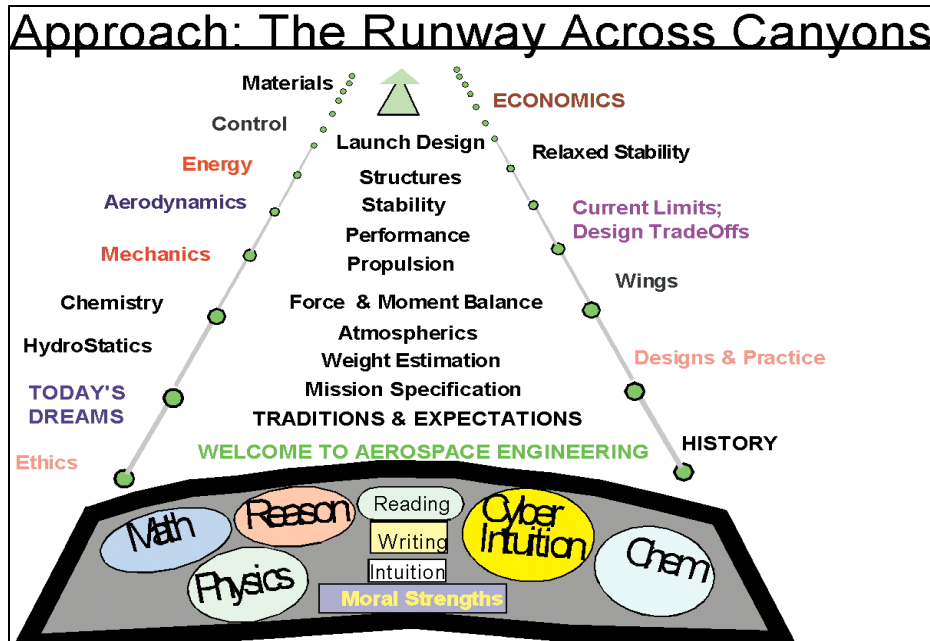
Figure 7

LEARNER-CENTERED VIEW OF THE KNOWLEDGE BASE

Our concept of the expanding knowledge horizons of a new learner in a discipline is inverted from the structure of specialization. Beyond the design-based portal is the core. We followed Rechtin's synthesis approach (Ref.3)] to this problem with its infinite variety of paths to the content. This approach tackles the chicken-or-egg dilemma between creating content and structure for a large and unknown system. A prototype is created, enabling its performance to be studied in order to determine optimal structures for the full-scale system.
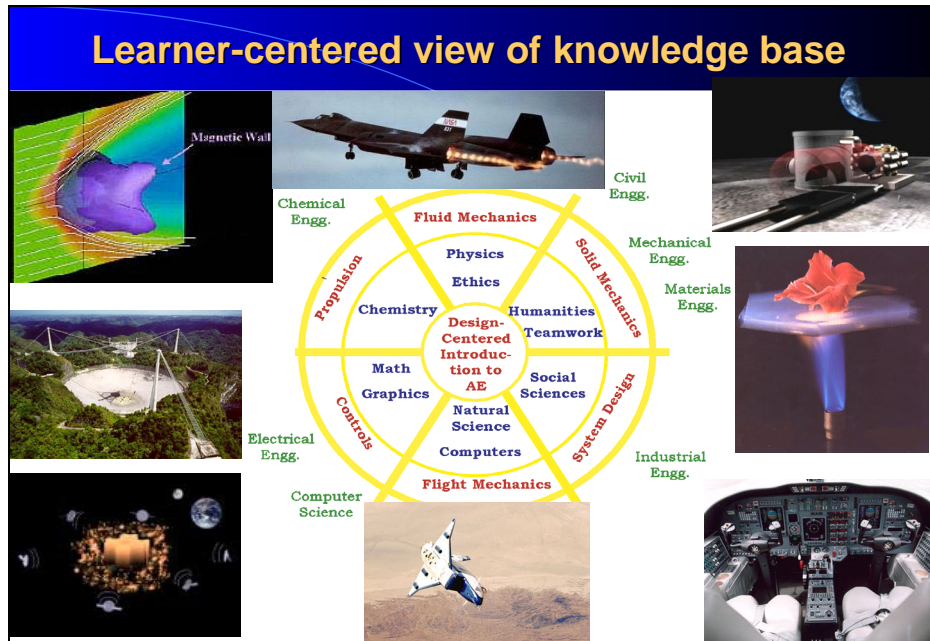
Figure 8

AEROSPACE DIGITAL LIBRARY PORTAL

The front portal was designed to (a) provide fast access, and (b) to cater to different learner preferences and needs. Links were provided to the theory, archives, and other resources. A front panel provided links of interest to aerospace engineers, such as weather information, a Periodic Table, a Standard Atmosphere, and search engines for the Internet and the ADL. A selection of digital libraries from all over the world was linked. A Hyperbolic Tree site map serves learners who prefer a visual perspective of the ADL. Beyond this, two access methods were provided. The first was through the courses into higher levels of specific disciplines. The other was a table of subject areas. Resources were sorted into 9 different categories – as a starting point to hunt further with proper guidance. A Publication Archive was deployed in summer 2002.
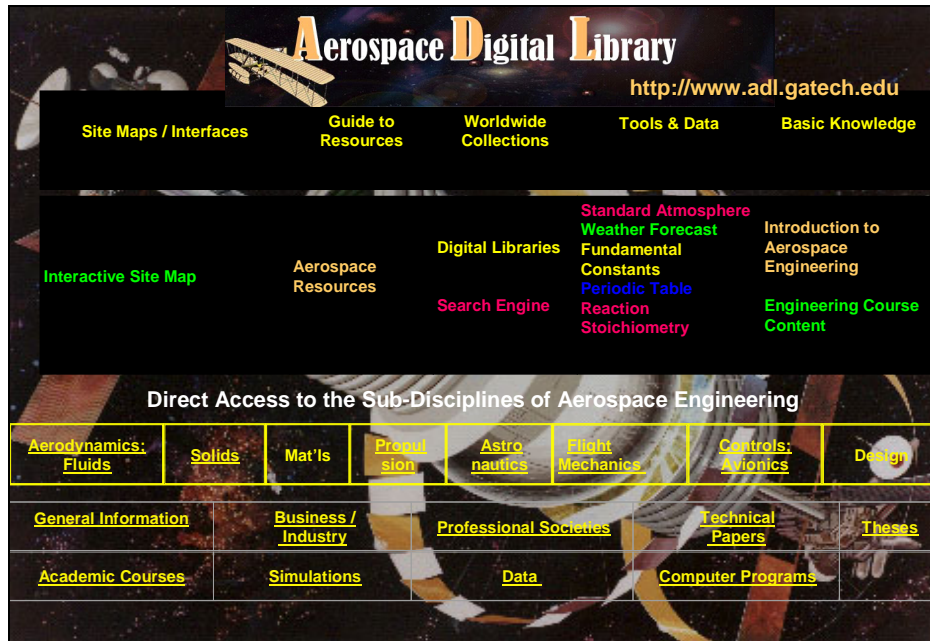
Figure 9

OTHER DISCIPLINES

Links to other disciplines of engineering and science are provided. As a start, these links are to the websites of schools dealing with these disciplines. We hope that dedicated gateways similar to our Aerospace gateway will be found in each of these disciplines in a few years, at which point the student can intuitively proceed from one discipline to another, gaining perspective as well as lucid introductions and expositions from the experts in each discipline.
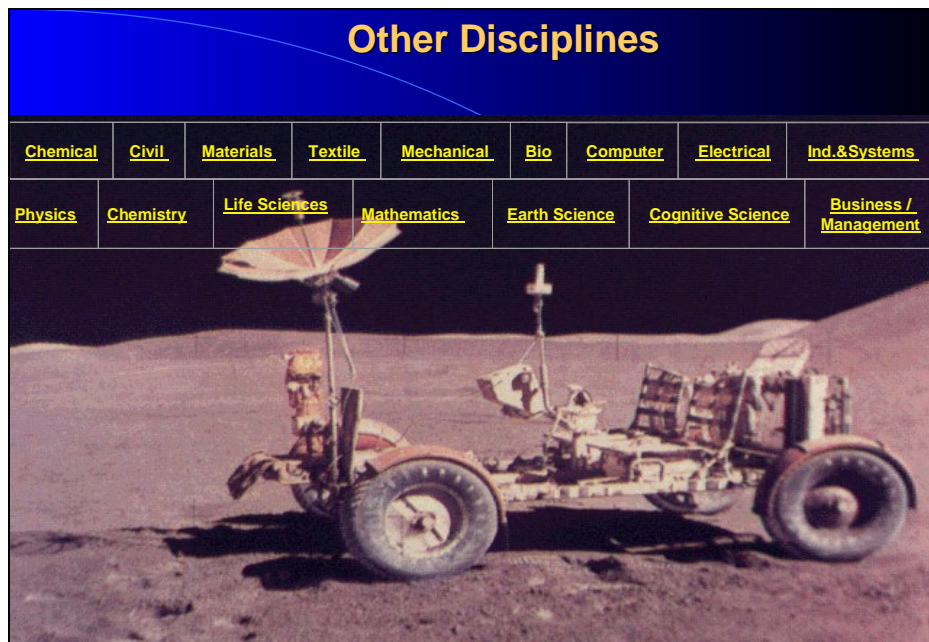
Figure 10

TECHNOLOGY IN LEARNING

The role of technology in the learning process is a subject of constant thought. Technology enables many dreams to be realized. One can revisit concepts and methods from many viewpoints, perform collaborative projects involving real-world complexity, learn in team environments, and cross boundaries between levels and disciplines seamlessly. These should of course enhance both vertical and horizontal integration of learning, and develop learners with much better perspective as well as grasp of the subject matter, enabling them to learn to solve problems anywhere.

The role of technology inside the classroom is not so clear. We have long been skeptical of the usage of technology to demonstrate techniques which people used to learn by reading and experimentation before. Observations of Georgia Tech aerospace engineering students shows that many do in fact prefer simple, fast-loading websites, and are used to learning from textbooks and in-depth, detailed derivations. These aspects may be evolving as newer students arrive with a different set of aptitude, expectations and experience with using computers and the internet.
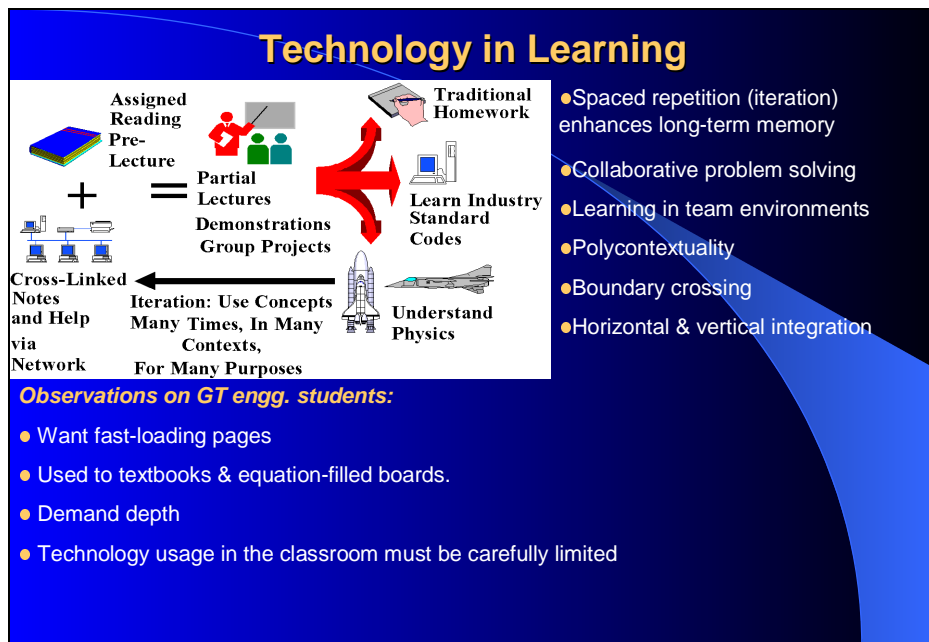
Figure 11

REALITY CHECK FOR COURSE REDESIGN

Ideas such as "course redesign" and "technology use in the classroom" must be subjected to stringent reality checks. Alumni and employers expect that the value addition by a university education includes the experience of solving difficult problems under somewhat adverse conditions. While this is no excuse for persisting with needlessly adverse environments, it is important to ensure that as previous obstacles to learning are removed through redesign and technology, the students are not denied an once-in-a-lifetime opportunity to learn to deal with challenges.

One criterion which has found acceptance is that of enabling the top performers in our classes to turn out better products and performance. The other criterion of reducing drop-out rate is more relevant to the first two years. These views often trigger negative reactions from education experts unfamiliar with the engineering leaning environment.

Figure 12

EXPERIENCE WITH ADL

The Aerospace Digital Library is in its fifth year of classroom usage at Georgia Tech. The resource is used by students at all levels – from first-year undergrads to PhD candidates. Types of usage are indicated in the figure.

Figure 13

STUDENTS USE ADL IN MANY WAYS

Project teams use the web site for "Knowledge Management", storing documents for common access, and an electronic forum, maintaining continuity across years,. These students range far outside their home disciplines. Links to digital libraries on Shakespearean literature and classical poetry find usage, as do NASA resources. Seniors in aerodynamics classes cited discussions with faculty in Germany and Australia about computer codes. Codes from the University of Sydney, data from Japanese and Indian sites, and papers on flapping wing flight from England have all found usage. It is interesting to note that despite heavy usage in our own classrooms, 70% of total usage comes from outside Georgia Tech.
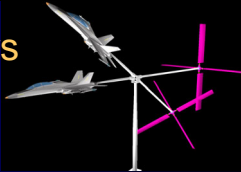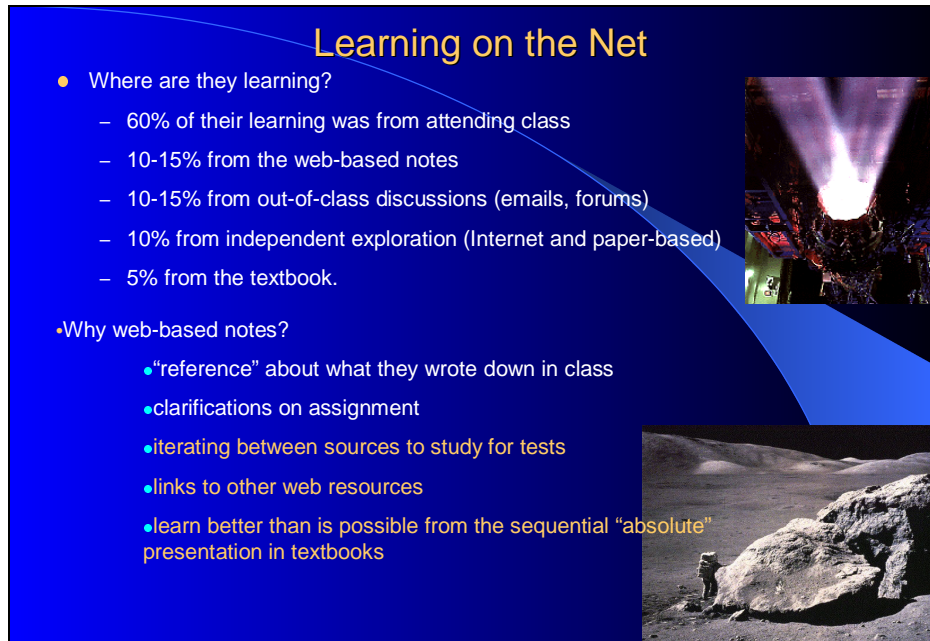
Figure 14

LEARNING ON THE NET

Asked how much of their learning was from each source, the near-unanimous answer was: 60% from attending class; 10-15% from the web-posted notes; perhaps 10-15% from out-of-class discussions and e-mail exchanges with the instructor, 10% from independent exploration, and 5% from the textbook. The web-based notes are still new enough that most students print them like class notes. The comfort level is not yet adequate to make the digital resource the primary means of learning – a necessary step for routine cross-disciplinary learning. Internet usage by project teams is heavy and ranges across areas where students have not had formal courses. Here, students gravitate to the "lighter" presentations, shunning derivations and in-depth explanations. Many learners feel overwhelmed by the Internet, and the challenge of prioritizing. Surprisingly few cited difficulties with nomenclature and terminology. The ability to study material through different approaches and nomenclatures is an encouraging sign. In no case has the availability of digital resources reduced in-class attendance. In fact, human interaction and guidance are appreciated more emphatically.

Figure 15

CONCEPT MODULE PRESENTATION

The idea of developing "Concept Modules" has found strong acceptance from learners. Opinion is divided on preferences for various approaches to developing these essays. As Concept Modules get more interactive features added, and enable input and evolution, they are more appropriately termed as "Concept Engines".

Figure 16

OBSERVATIONS ON WEB-ASSISTED LEARNING

Present students still prefer to download web notes and use them like textbooks – they are not yet fully comfortable with learning straight off the internet. This inhibits us from extensive cross-linking – the downloading requirements would overwhelm students. Many already cite difficulties in prioritizing what to learn.

Predictably, students tend to prefer the "lighter", less mathematical treatments. However, it is interesting to note that treatments in different sub-disciplines, using different nomenclature, have not triggered any significant complaints from learners, when the context is properly explained.

It is very interesting to note that even when the entire course notes are posted on the web, class attendance has not gone down – on the contrary, the value attached to human interaction in the learning process has gone up.

Figure 17

CROSSING DISCIPLINE BOUNDARIES

People indicate a preference for a familiar interface. Thus learner-centered nodes are needed in each discipline, cross-linked to facilitate access. On the other hand, learner preferences vary greatly even between classmates – necessitating multiple structures for the links to the material. Given an essential core of in-depth material and broad concept explanations, it appears that users are happy to do their own searches, making it irrelevant whether the cross-disciplinary resources are linked or posted on ADL itself. This is a very encouraging finding on how people prefer to learn across disciplines.
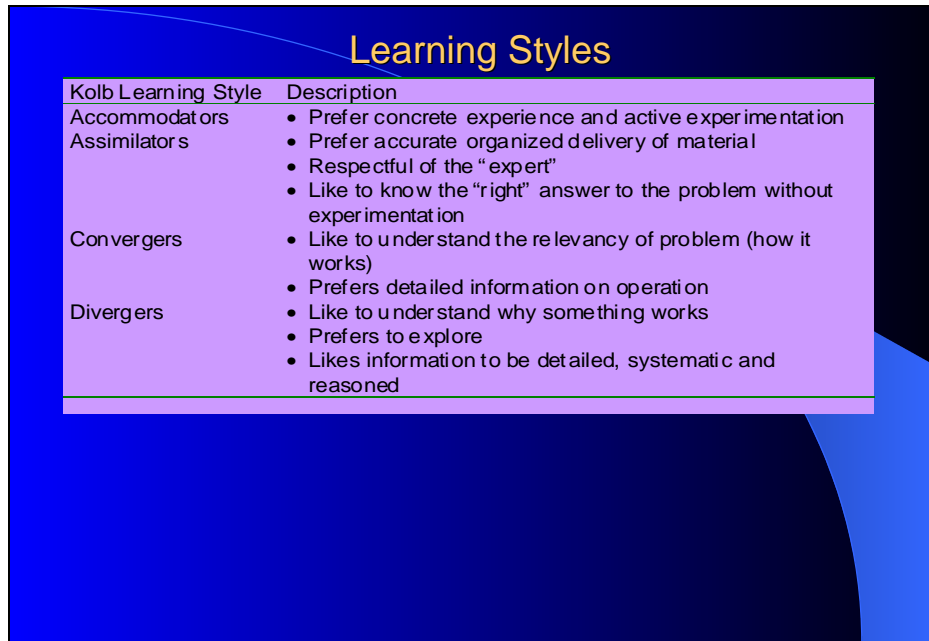
Figure 18

LEARNING STYLES

The existence of different learner styles is well-known in the literature. Differences in learner types have been cited even within a single discipline – thus it is certain that there will be wide differences between learner preferences when learning across disciplines. It may be impossible to design learning materials to suit all learner types simultaneously. An interesting possibility of web-based learning is that it is possible to tailor the presentation of given material, transparently, to the user – so that each user sees material organized according to the preferences that s(he) exhibits.

Observation of students also suggests that engineering students will evolve in their learning styles, and in fact the same student may prefer to learn different subjects with different styles!

Learning Styles

Kolb Learning Style	Description
Accommodators	• Prefer concrete experience and active experimentation
Assimilators	• Prefer accurate organized delivery of material
	• Respectful of the "expert"
	• Like to know the "right" answer to the problem without experimentation
Convergers	• Like to understand the relevancy of problem (how it works)
	• Prefers detailed information on operation
Divergers	• Like to understand why something works
	• Prefers to explore
	• Likes information to be detailed, systematic and reasoned

Figure 19

INTERFACES TO SUIT LEARNER TYPES

A set of possible metaphors for different learner styles in the field of aerospace engineering is given in the figure.

Interfaces to Suit Learner Types

Interface	Astronaut	Eagle	Barnstormer	Rocket Scientist
Learner Style	Sensory/ sequential	Global / Intuitive	Global / sensory	Intuitive
Emphasis / Presentation	Sequential Inductive organization.	Site-maps -free to pick precise items quickly	Perspective. Theory linked: problem-based approach.	Theory. Hyperlinked derivations; use of mathematics.
Reasoning	Inductive /Active Processing	Inductive / deductive	Inductive/ deductive	Deductive/ Reflective Processing
Resource Types	Modules Point summaries Re-iteration Examples	Database subject; glossaries; Insight Hyperbolic Tree; Site Maps, charts.	Concept Engines, Data Graphics. Examples, Calculators	Theorems; proofs. Logic, Original papers. Concept Engines. History.
Inp. emphasis	Auditory	Visual	Kinesthetic	Auditory

Figure 20

OTHER REACTIONS

Reactions from the professional community show an interesting dichotomy. Alumni of engineering programs such as ours are positive and comfortable with ADL resources, expressing delight at desktop, on-demand access to course notes. These users have also contributed several items for informal publication, urging usage in classes. Usage by other professionals is not yet known to be significant. The idea of being able to find reliable in-depth resources and guidance on the web is new. Among other faculty, there is a dichotomy between those who appreciate, and others who reject, the necessity of teaching to solve problems across disciplines. Given that these are representative of engineering faculty, major obstacles remain in getting widespread faculty participation.

Other Reactions

Engg. Alumni: positive and comfortable with ADL resources, cite desktop, on-demand access to course notes.

Contribute items for informal publication, urging usage in classes.

Other professionals: Usage not yet known to be significant. The idea of being able to find reliable in-depth resources and guidance on the web is new.

Other faculty: Dichotomy between those who appreciate, and others who reject, the necessity of teaching to solve problems across disciplines.

Figure 21

STEADY-STATE SELF-SUSTAINMENT

As we enter the 5th year, we have shown steady-state self-sustainment at a moderate but useful level of existence and growth. Local storage is under 1.6 GB - a small fraction of the linked resources. In May-July 2002, the "background" usage – absent any courses requiring ADL usage – showed 135 unique users per day, compared to 87 in April 2001, with heavy undergraduate and graduate classes usage. Web-page requests per day have gone down from 3500 to roughly 1500. This is because our own students do more downloads in their courses. Also, a new site search engine has helped focus searches. The Design-centered interface is heavily used, as is the undergraduate-level course content. This is the most useful material to users across geographic and discipline boundaries.
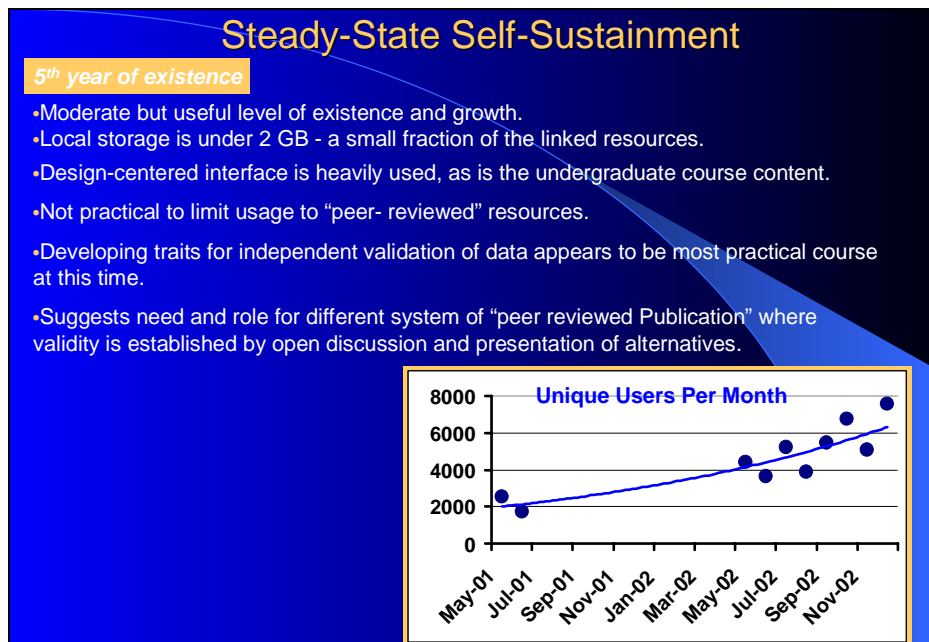
Figure 22

EXAMPLE APPLICATION: EDUCATION FOR A SPACE-BASED ECONOMY

ADL is being used to help student teams engaged in developing a picture of the Space-based economy and its evolution – from the launcher industry of the 1950s and 60s, to the exploration and research, and on to today's communications industry, with the first space stations being developed. This is projected to extend, as refuelling and maintenance businesses develop, into development of lunar resources, habitats, a service economy, and eventually a full-fledged Space-based economy. NASA programs like the "NASA Means Business" program from the Texas Space Grant and JSC, and the NASA Institute of Advanced Concepts, provide the starting point for this effort.
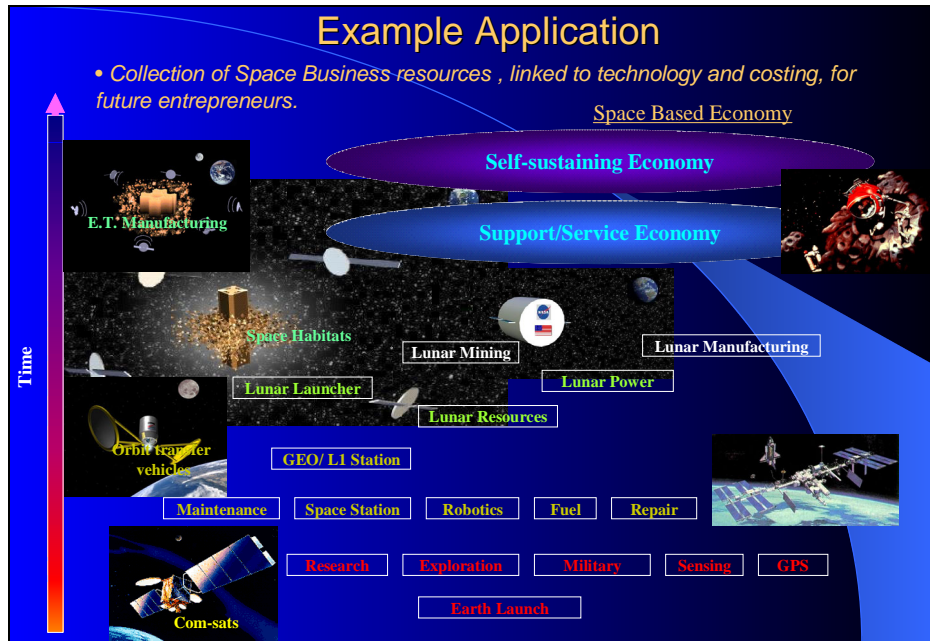
Figure 23

EXAMPLE APPLICATION: "THERE'S SPACE IN YOUR FUTURE"

Cross-Disciplinary knowledge resources permit better articulation of the opportunities related to Space-based businesses which can open up for people who consider themselves to be far removed from aerospace technology.

Figure 24

FUTURE DIRECTIONS

Our efforts are shifting from resource acquisition to content refinement, cross-linking and adaptation to learners. It also appears that the "digital library" may be outmoded as a metaphor for an active learning environment, since the term "library" holds less meaning to many current students, who do their learning straight from high-speed internet links to their dormitory rooms.

As alumni express the continued utility of ADL resources, it appears that the active engineering environment which provides impressive advantages to the modern engineer, is within reach.

Figure 25

SUMMARY

The objectives in the first phase are summarized in the figure.

Summary

Learner-centered resource for learning engineering fundamentals and solving problems across levels and disciplines. Specific objectives were:

• Develop core of fundamental knowledge on several disciplines accessible through the Internet, sufficient to form a useful learning resource for various levels.

• Develop user experience in courses and research programs as a learning resource.

• Assess learning methods and curricular structures enabled by these resources.

• Test hypotheses about self-sustainment, growth and self-organization.

First phase of the development - demonstrated self-sustainment and moderate growth in content and relevance to learners worldwide.

Figure 26

SUMMARY: WHAT IS ENABLED TODAY

The ADL has already enabled several desired features of engineering education, as listed in the figure.

Figure 27

CONCLUSIONS AND ACKNOWLEDGEMENTS

Our system approaches cross-disciplinary learning within the constraints of present curricular structure. We find it essential to take learners through familiar environments that resemble their courses and class notes. As internet-era students arrive in college, the comfort level with digital resources has risen. The challenge is to develop the willingness to delve into rigorous studies. Learners still must receive a great deal of support and guidance. Professional users from industry appreciate the convenience and depth of such resources, but stay within discipline constraints for the most part. It became apparent early that the unique value of the cross-disciplinary learning environment comes from 3 features:

- The core discipline material, with explanation and examples for understanding concepts and solving problems
- Selected links to outside resources
- The sorting of other resources into logical areas, and the guidance to the learner.

Figure 28

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[3]   Rechtin, E., "The Synthesis of Complex Systems". IEEE Spectrum, 34,7, July '97, p. 51 - 55.

Institute for Advanced Education in Geospatial Sciences Educating the Next Generation of Scientists

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The University of Mississippi
University, MS

THE INSTITUTE FOR ADVANCED EDUCATION IN GEOSPATIAL SCIENCES

       The Institute for Advanced Education in Geospatial Science (AEGS) is a project funded by NASA at the University of Mississippi. It seeks to support the NASA Earth Sciences Enterprise efforts to optimize NASA's Earth Science investments for the benefit of the Nation. This presentation describes the basic work of the project, its goals, history and progress to date. The project is in year two funding of a potential five year funding.
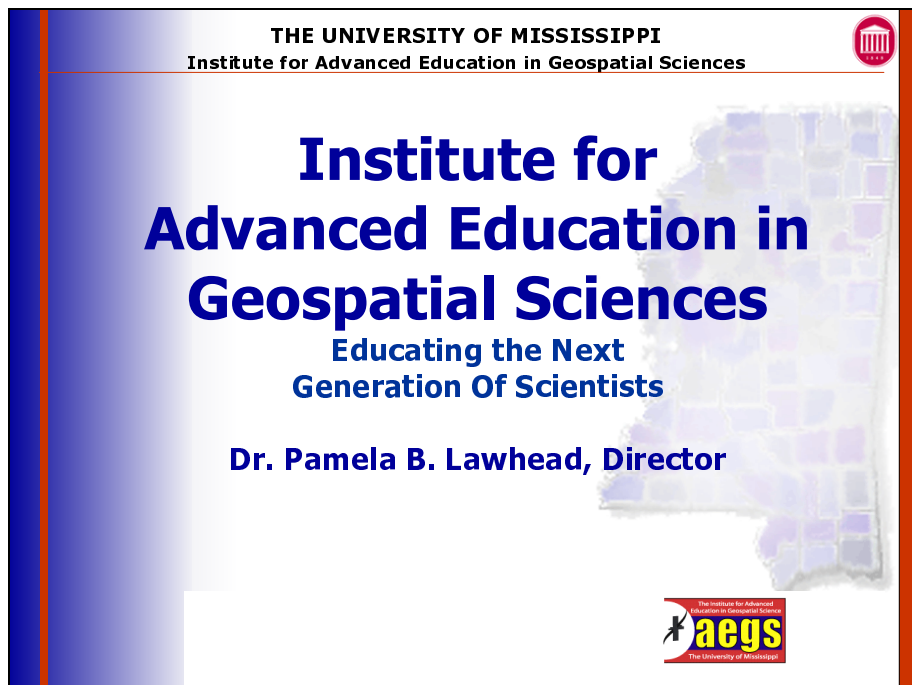
Figure 1

THE PROJECT

The project, as stated earlier is sponsored by NASA and is located at the University of Mississippi in Oxford, MS. It has two principal investigators with one of them, Pam Lawhead, serving as the Director of the Institute.

The goal of the project is to create fifty online courses in Remote Sensing over the five year life of the project. Each year ten courses are put out for bid and the best ten submissions are accepted. This request for proposals insures that the course creators are content experts. "Equivalence of product" drives the online hosting of the courses. That is, we want the online presentation and delivery of each course to be as multi-media intensive as is effective. The goal is not to replace existing courses but, to provide courses created by content experts to as many colleges and universities as possible. This effort to create and host online courses has as its final goal the creation of a very large college educated workforce prepared to use the vast stores of information gathers by NASA and other remote sensing industries to enhance life on this planet.

Figure 2

PROJECT GOALS

Historically, little has been done to provide a consistent curriculum in Remote Sensing. This project has as its goal to do that first and then to move forward with its other efforts. To that end, we entered into a partnership with the American Society of Photogrammetry and Remote Sensing (ASPRS) to help us identify Academic and Industrial leaders. Once these individuals were identified, they were brought together to develop a robust, integrated curriculum.

Once the curriculum was identified, courses were prioritized and sets of courses were designated for each year. By following the outline of the committee ten courses were created for each of the first two years of the program. The committee will meet again in October, 2003 to work on year three courses. Following this process either fifty courses or its equivalent will be written and enhanced for online delivery by the end of the funding period.

In order to insure the widest range of acceptance and to provide a true equivalence of product a state-of-the-art course delivery system and creation process has been developed. This process is being tested as this presentation is being written.

Figure 3

ALIGNMENT WITH NASA EARTH SCENCE SYSTEM'S NATIONAL APPLICATION AREAS

NASA's Earth Science Enterprise, Applications Program and Applications Directorate have identified three missions:

"To develop a scientific understanding of the Earth system and its response to natural and human-induced changes to enable improved prediction of climate, weather and natural hazards for present and future generations."

"Expand and accelerate the realization of societal and economic benefits from Earth science, information and technology."

And finally: "To optimize benefits from NASA's Earth Science investments through systems engineering to advance decision support tools that serve the nation."

To be consistent with that enormous effort we have made very attempt to be sure that our courses are in alignment with these missions. The following figures demonstrate that alignment by listing the current and future courses that alignment with each of the identified application areas.

The figure below shows the first of these areas and the courses consistent with Agricultural Competitiveness.
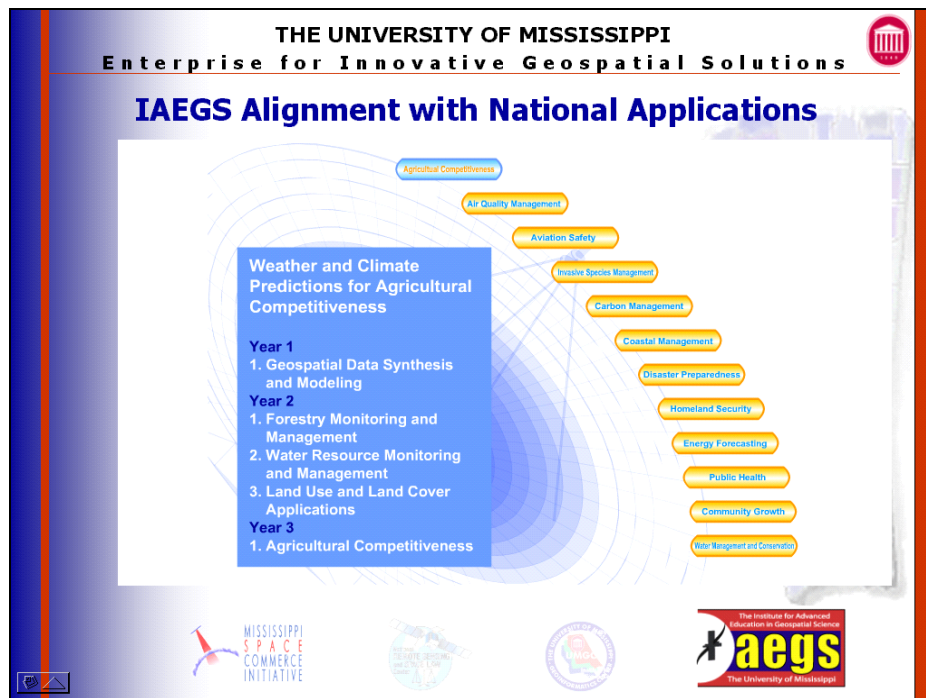
Figure 4

ALIGNMENT WITH NATIONAL APPLICATIONS
AIR QUALITY MANAGEMENT

In year one we have one course that meets this application area, Geospatial Data Synthesis and Modeling/

Year two will have two courses in this area. The authors of the courses Land Use and Land Cover applications and Community Growth will be selected at the June 9th-10th meeting to be held in Oxford.

Year three will have a course in Air Quality Management. The full description of that course will be written by the members of our National Advisory board in October.

Figure 5

WEATHER, CLIMATE AND NATURAL HAZARDS PREDICTIONS FOR AVIATION SAFETY

The course that addresses this issue, Aviation Safety will be written in the October meeting and then put out for bids in the spring of next year.

Figure 6
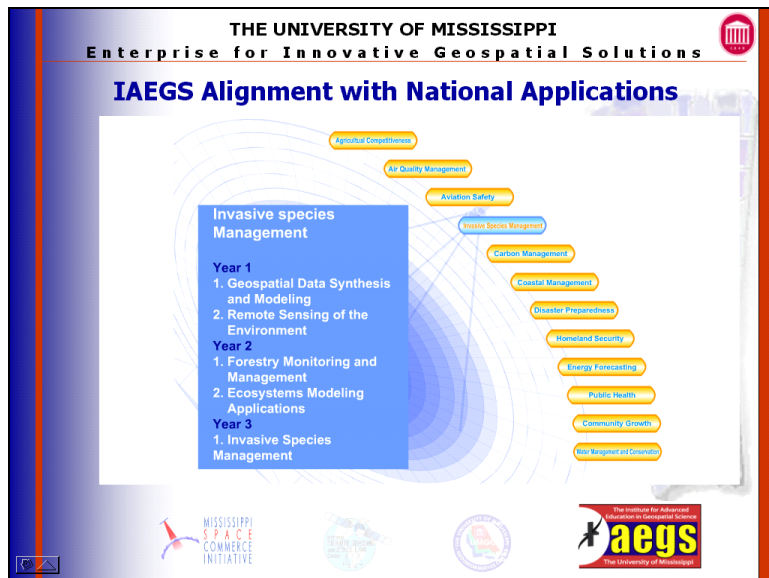
Figure 7

PROPOSALS

Once the course descriptions were completed a request from proposals was created and published. It was sent to the several professional organizations membership lists; it also appeared on our web site. Thirty proposals were accepted and the authors were invited to participate in a forum where the proposals were formally reviewed. Nine proposals were accepted and their authors were awarded sub-contracts of $80,000 each.

The authors were then invited to a workshop in August where they were introduced to the course creation process and to their course liaisons.

Figure 8

THE COURSE FELLOWS

The course fellows and their affiliations are listed below. The Lidar course was not awarded because there was not a strong proposal for it.

Figure 9

THE COURSE CREATION PROCESS

In order to build a course on line the Institute provides graduate students in a technology lab for each course fellow. The fellow is responsible for the course content only. That content may be delivered to the center in any way that the fellow feels comfortable. We have set up an online delivery process but some fellows found it difficult to use or preferred to give us the material in other ways. Once the material is presented to the student liaisons, it is enhanced, broken up into acceptable sizes and hosted online. The student liaisons work very closely with the fellows. We also provide an educational consultant for the fellows. This person is responsible for guiding the fellows in the development of very detailed course concept hierarchy maps.
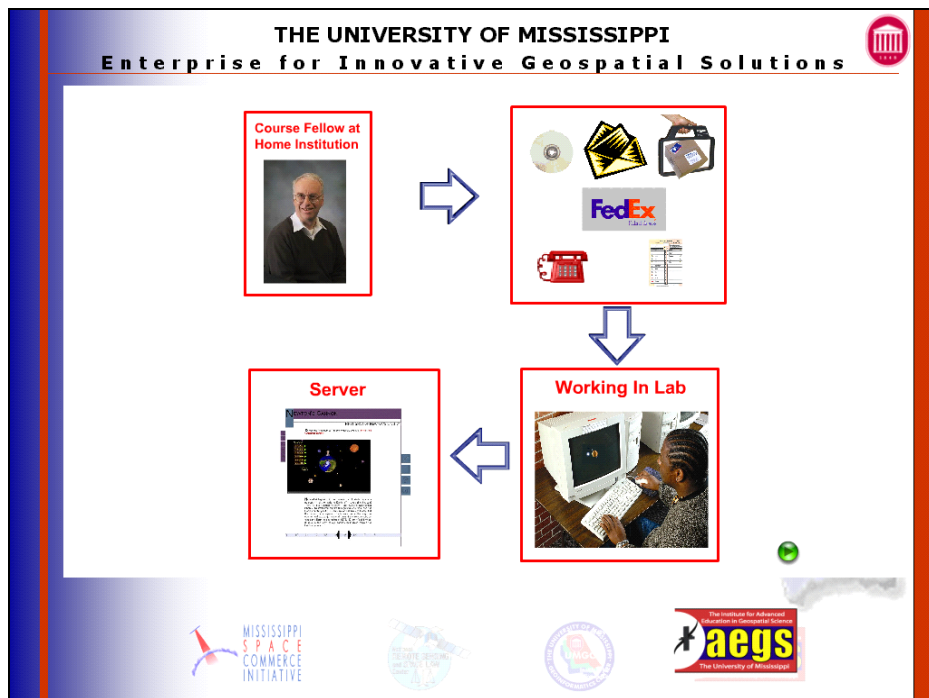
Figure 10

THE PROGRAM DELIVERY SYSTEM

On the programming side the course delivery system is divided into four parts, the user interface, XML/XSLT templates, publishing framework and the backend database. These are used to produce each course page.
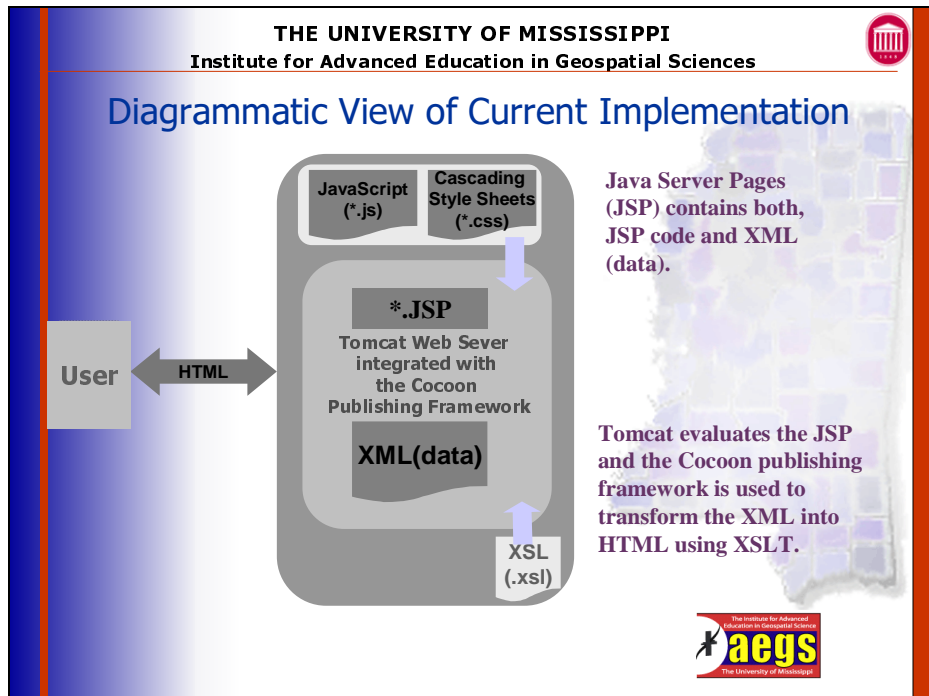
Figure 11

THE COURSE DELIVERY SYSTEM

The delivery options for each course are varied. A student may enroll at any college our University, anywhere and access the courses. The home institution licenses the courses from the Institute. The home institution awards the credit to the student, gives grades and basically oversees the administration of the course locally.

Figure 12

CURRENT STATUS

We have currently hired a staff of four, a director, an associate director, a project coordinator and a network administrator. We have thirty graduate students at work. These students are divided into five teams and within those teams have multiple responsibilities. Some students are members of multiple teams. Student liaisons are responsible for identifying work to be done for each course and then parsing the work out to others. All students are members of the research team and expected to be actively involved in some research topic related to the course creation/ delivery process.

Figure 13

CURRENT STATUS

As discussed earlier, the Advisory Board is an active part of the Institute's work. The technology lab is established with students working actively each day. Two prototype courses are complete. Two other courses are 90 % complete and all others are approximately 60% complete. One short course is in process on Decision Support Systems.

We work very closely with our educational expert in directing the overall design of each course. We have a very large group of graduate students at work and are, for the summer, using some undergraduates.

Figure 14

STATUS

The Knowledge Engine, described earlier is complete and undergoing testing at this time. The Virtual Portal is being completed, including the Virtual Campus and the browser application.

The course fellows are all under contract, the second round of RFPs will culminate in a conference on June 9th of this year. The goal is to have six courses out for testing by the end of this summer.

Figure 15

RESEARCH RESULTS

The articles listed below are evidence of the effectiveness of the work of the research team. This is the status as of April, 2003. There are many more papers under construction at this time. It should be noted here that, because of our successful International work we have had a name change. In the research papers our name appears and the Center for Geospatial Workforce Development (GWD) we are now the Institute for Advanced Education in Geospatial Sciences.

THE UNIVERSITY OF MISSISSIPPI
Institute for Advanced Education in Geospatial Sciences

Current Publications By The Institute

Liang Feng, **Application of Database Technologies in the GWD Online Course Creation Project,** Conference Name: The 2003 International Conference on Information and Knowledge Engineering (IKE'03) Feb.17, 2003

Hong Zhou, **Naive Bayesian Classifier for Microarray Data.** International Joint Conference on Neural Networks, July, 2003

Jun Liu **Three-Dimensional Effects Created by Macromedia Flash MX,** The 2003 International Multi-conference in Computer Science and Computer Engineering Draft Due: Feb 17,2003.

Jie Tang **Follow the Line: using vision in an autonomous mobile robot,** The 4th British Conference "Towards Intelligent Autonomous Robots" (TIMR '03) Draft Due: 4/25/03

Figure 16

MORE RESEARCH PAPERS

These paper topics indicate the scope of the work being done. The paper by Bhatt explores the work of using Virtual Reality to provide online laboratories in GeoSpatial Sciences. The others all have to do with technical issues regarding the delivery of the online courses or the creation process itself.

Figure 17

Figure 18

PUBLICATIONS CONTINUED

This list continues the papers written by members of the research team. The list goes from policy issues to Adaptive Learning. Again, it is important to note that these papers are a reflection of the issues that we work on at the Institute and are critical to the success of the projects.

Figure 19

RESEARCH CONTINUED

Mr. Paris is the team lead on the Virtual Portal, he also is doing significant work on data compression both for course image delivery but for compression used in other areas as well.

Figure 20

COURSE LIST

The list below is the set of courses that are currently under construction. We expect to have courses, 3, 4, 5, 7 and 10 ready for delivery by the beginning of the Fall semester.

Figure 21

YEAR TWO COURSES

The descriptions and the RFP for the courses listed here can be found at the Institute's web site: http://geoworkforce.olemiss.edu.

The meeting to determine the authors for each of these courses will be held on June 9, 2003. The fellows will then return to the campus for a workshop in August to begin the course creation process.

Figure 22

INTERNATIONAL EFFORTS

Round one of the course selection process had applications from Greece and Canada. This was only the beginning of our International effort. We spoke to the ISPRS Council and Commission heads in December where we received their endorsement. We are in the earliest stages of working with CEOS in an effort to achieve a global market.

Year three will be very involved in "internationalizing" the curriculum to insure that it has as large an audience as possible.

Figure 23

OUTSTANDING CHALLENGES

The Institute still faces many challenges, none insurmountable but all are there before us. We are in the process of completing the licensing process. This requires a formal document which must be acceptable to our own institution as well as the subscriber institutions. It is being reviewed as this is being written.

Web deliverable 3-D has a significant overhead that must be dealt with if the speed is to be acceptable. We are working on this on many fronts. We are working to reduce the files size, to compress and decompress the files, to use streaming and caching techniques.

We are testing the delivery process on many levels, not just the speed but also the understandability of the interface as well.

It is our hope that the second version will be filled with existing learning style technology.

Figure 24

THE VIRTUAL PORTAL

The virtual portal is nearing completion. We have the Portal sending information to the Browser but we must complete the loop and have the information flow in both directions. This is simply a programming issue and it is being solved.
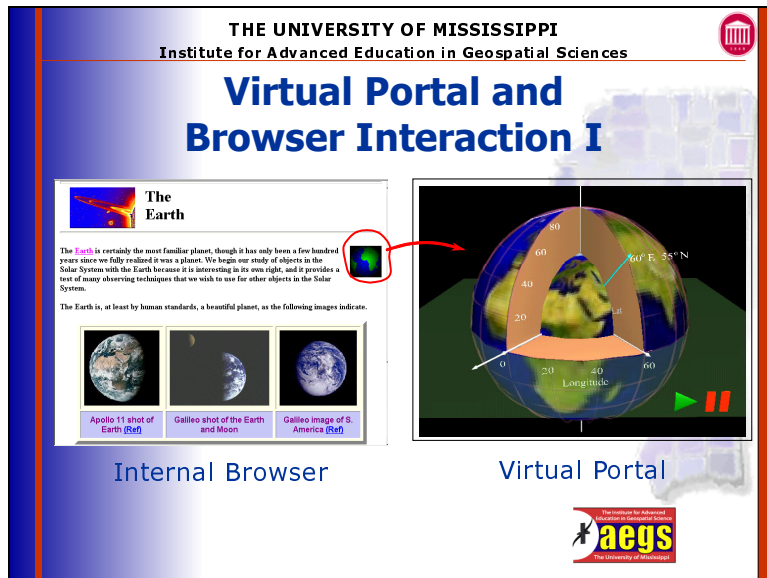
Figure 25
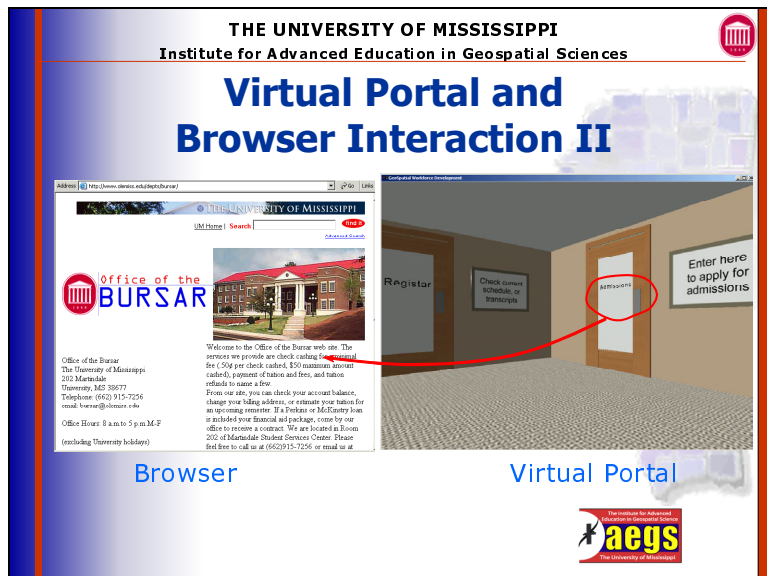
Figure 26

THE FINAL PRODUCT

The image below reflects the final project. In it there is a standard browser, a video chat space, a white board, the 3-D virtual portal, a note pad and a list of who is online as the student is logged on. This will be the space used by the students.
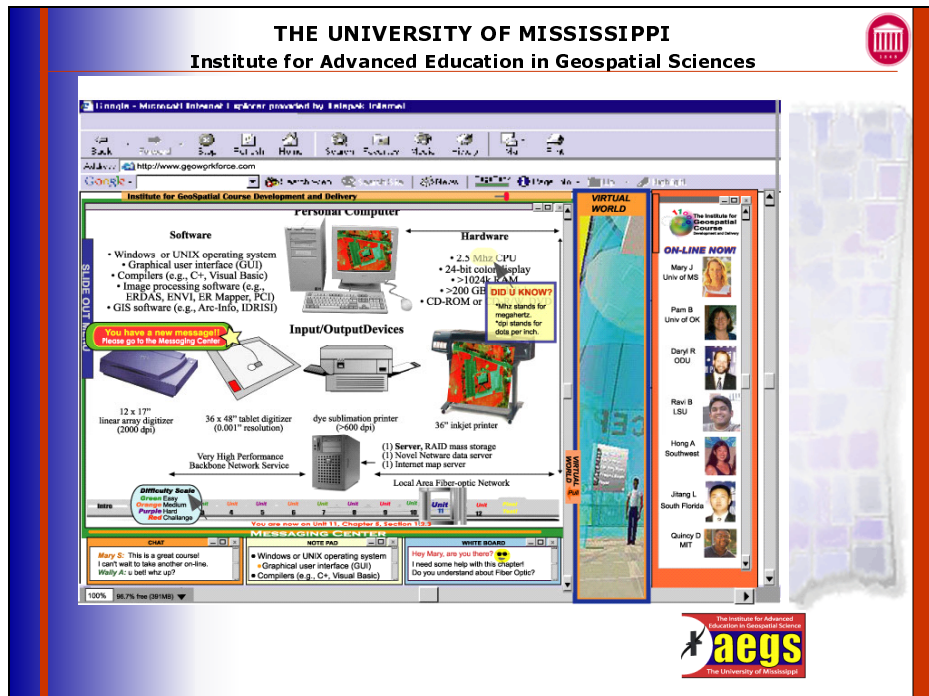
Figure 27

THE WEB PAGE

This is a snapshot of our web page which can be viewed at
http://geoworkforce.olemiss.edu
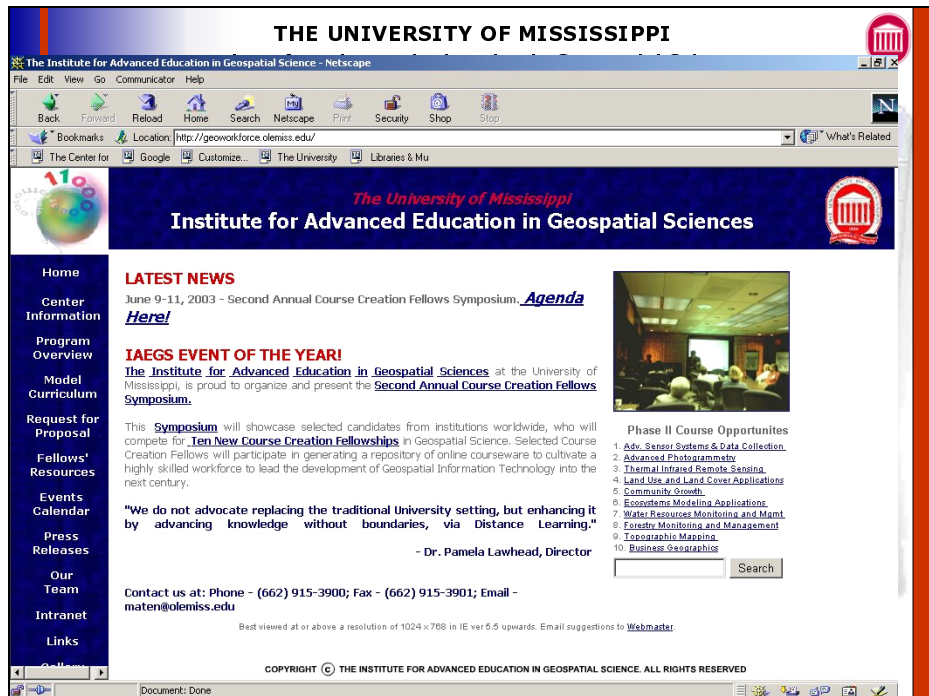
Figure 28
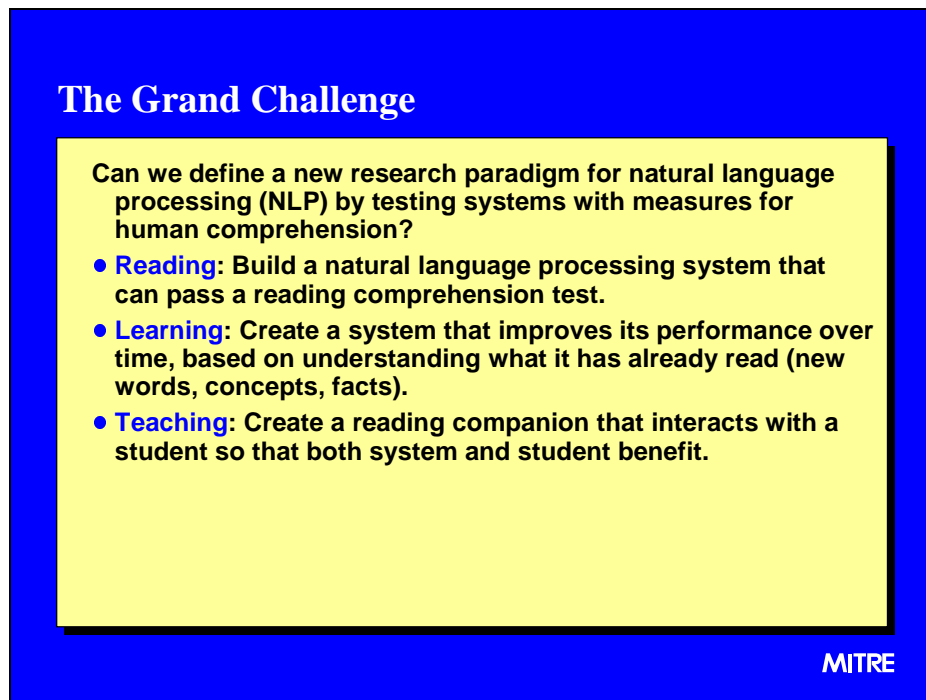
Reading, Learning, Teaching

Lisa Ferro, Warren Greiff, Lynette Hirschman, Benjamin Wellner
Information Technology Center, the MITRE Corporation
Bedford, MA

THE GRAND CHALLENGE

The project described in this presentation is part of MITRE's larger ongoing research program in natural language processing (NLP) technologies, to include information extraction, information retrieval, question answering, speech, and dialogue. For the past several years, a handful of us have been working on developing a research paradigm in which we evaluate a computer's understanding of language using the same tools and techniques used to evaluate a human student's understanding of language. We have divided this project into three parts: Reading, Learning, and Teaching.

The Grand Challenge

Can we define a new research paradigm for natural language processing (NLP) by testing systems with measures for human comprehension?

- **Reading**: Build a natural language processing system that can pass a reading comprehension test.
- **Learning**: Create a system that improves its performance over time, based on understanding what it has already read (new words, concepts, facts).
- **Teaching**: Create a reading companion that interacts with a student so that both system and student benefit.

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Figure 2

VISION OF THE FRAMEWORK

We are researchers in computational linguistics with an interest in education, rather than the other way around. We have thus been focusing our attention on developing a computer system that takes reading comprehension tests. But we are also interested in exploring how our system could perform as a peer learner in a larger teaching system. We have developed a primitive version of such a teaching system in order illustrate the interactions we envision. This teaching system will be described in greater detail on Figure 18. We would be very interesting in collaborating with education and learning technology researchers who could incorporate our reading comprehension system into a learning environment and test it with human students.
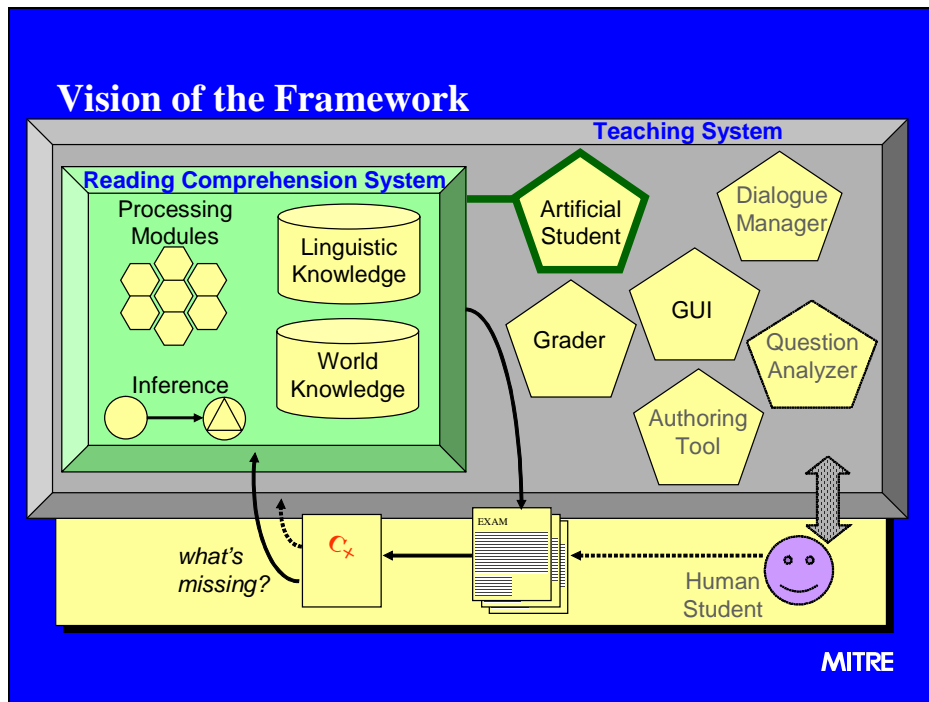
Figure 3

OUTLINE

This talk will first present more information about our current research program, then describe two of the reading comprehension systems we have developed. The second part of the talk will present the teaching environments explored under this research program.
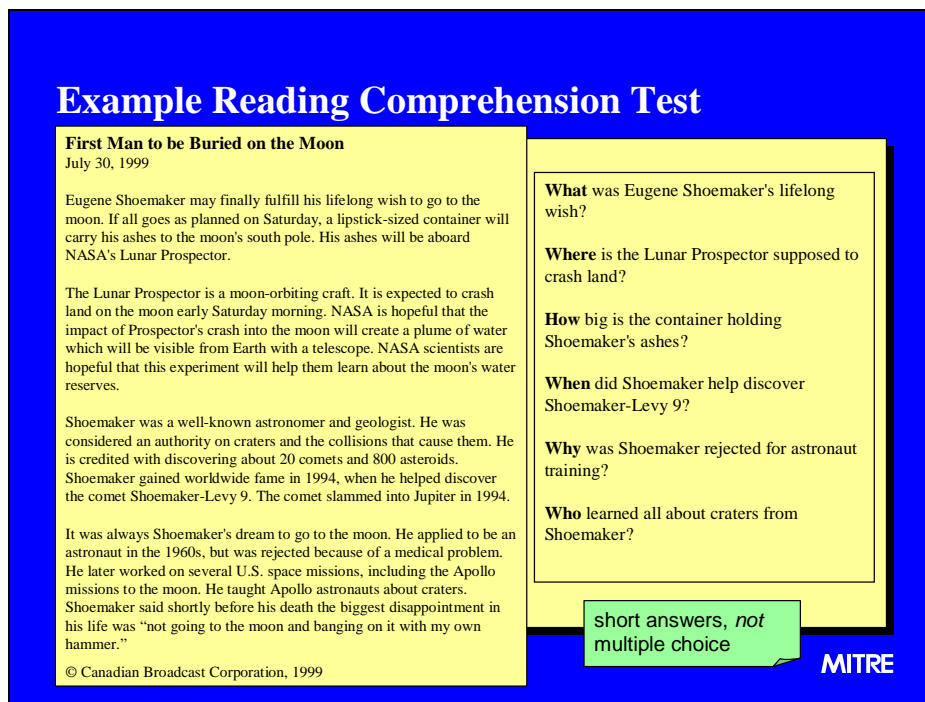
Figure 4

EXAMPLE READING COMPREHENSION TEST

Here is an example of one of the tests we use to develop and evaluate our reading comprehension system. It has a format familiar to everyone: a brief story plus a number of questions about the story. In order to make the research problem tractable, we have been using fact-seeking questions like the ones illustrated here. Reading comprehension tests also typically have questions such as "What is the author's position on this issue?" While we recognize that these questions are ideal for encouraging critical thinking in human students, they are extremely difficult for computer systems, so our current research has not included them. Note also that the questions are short-answer type, not multiple choice as one would expect in a standardized test. We chose short-answer questions to make the research task more realistic; Life, after all, does not generally give one choices. We wanted to build a computer system that could answer the questions, not merely select the correct one from a set of options.

Figure 5

WHY READING COMPREHENSION TESTS?

There are a number of reasons why we are using reading comprehension tests to drive our research. One is that they provide a means to measure the system's capabilities and report these measures in a way everyone can understand. Another is that by basing the research on collections of genuine reading material, the results of the research will more likely transfer to real-world applications. We also feel that the task of taking reading comprehension tests moves information technology towards deeper language understanding.   The task requires the computer system to understand not just the meanings of words, but how they relate to each other in the sentence (who is doing what), to understand how sentences relate to each other in the text, and the narrative organization of a text, such as temporal ordering of events. The questions are also completely open-ended, providing a true test of language skills rather than a test of specific domain knowledge or component skills such as name identification.

Why Reading Comprehension Tests?

- **Provides an intuitive evaluation metric.**
- **Grounded in genuine reading material (corpora).**
- **Moves information technology towards *language understanding*:**
  - **Entire texts:**
    - **How words relate to each other within a sentence (e.g., who's doing what)**
    - **How the sentences relate to each other (e.g., adding information, contradicting, changing topic)**
    - **The organization or narrative flow of the document**
  - **Open-ended: questions can be about anything.**

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Figure 6

DATA-DRIVEN RESEARCH PARADIGM

       The previous Figure mentioned the corpus-based nature of this research. This Figure explains in more detail how this type of research is carried out. We take a corpus (collection of texts) and divide it into three sets: training, development, and test. The training data is completely open to all the researchers on the project; it can be read and analyzed for patterns and content, or processed by machine learning algorithms. These activities result in the algorithms that perform the task -- in this case, taking a reading comprehension test. The development data is closed to the system developers. They do not look at it, but they can test the system's performance on this data and examine the results -- a type of "practice test," in other words. This process leads to further refinement of the algorithms. When the researchers are finally ready to see how the system is performing, they process the test data, which is data that neither the system nor its developers have ever encountered.
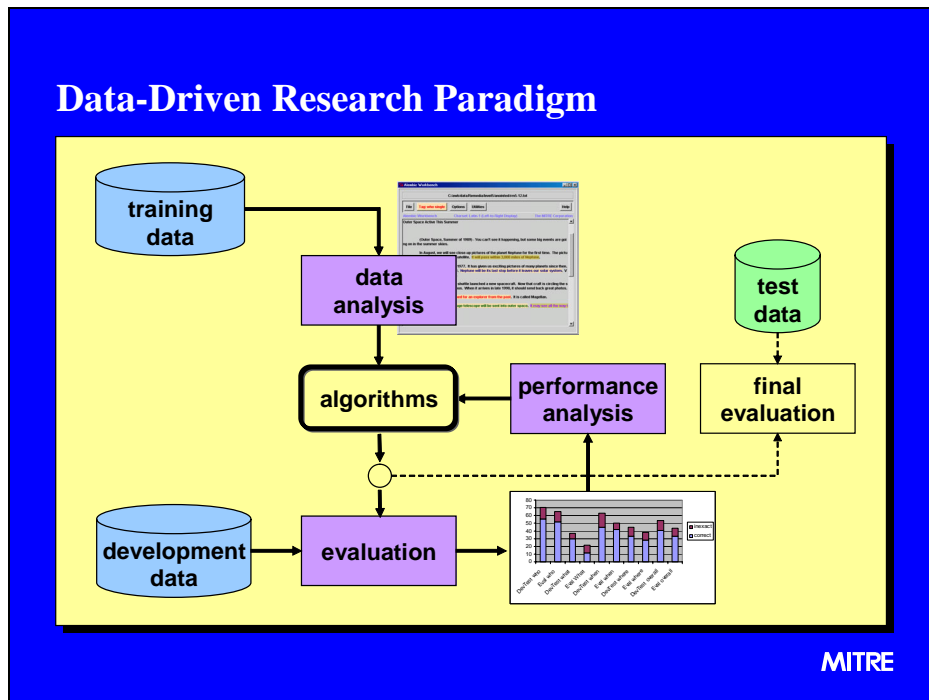
Figure 7

MITRE CORPORA FOR TRAINING AND EVALUATION

During the course of the Reading Comprehension research program we have created two separate data sets for developing and evaluating our systems. They both use texts based on a news story format. The Remedia Corpus consists of study materials for grade school children, purchased in hard copy form from Remedia Publications. The collection is divided into four sets of roughly 30 stories, with each set targeted to a different reading grade level, beginning at level 2. Accompanying each story are five short questions: *who*, *what*, *when*, *where*, and *why*. Each story is approximately 150-200 words in length. The CBC Corpus was compiled based on material from the Canadian Broadcast Corporation's CBC-4-Kids website. Each weekday this site posts a news story for young adults. Our corpus consists of 249 stories from the years 1999 and early 2000. We had professionally trained test item writers create eight to twelve questions for each story. The example story on Figure 4 comes from the CBC Corpus. In addition to the stories and questions, both corpora have undergone several types of linguistic analyses, and these analyses have been encoded into the text in the form of annotations. These include identifying names of certain entities and marking co reference, i.e., when a set of words each refers to the same entity.

MITRE Corpora for Training and Evaluation

- News story format
- Remedia Corpus
  - Study materials for grade school children, purchased in hard copy format from Remedia Publications.
  - Four sets of 30 stories, 150-200 words in length, each set targeted to a different reading grade level, beginning at grade 2.
  - who, what, when, where, and why questions, plus an answer key
- Canadian Broadcast Corporation (CBC) Corpus
  - 249 news stories for young adults, to which we added eight to twelve questions per story, plus an answer key
- Annotation: Names of People, Places, Organizations; Times and Money; Co-referring expressions (Jackie ↔ the pilot ↔ she)

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Figure 8

WORKSHOPS

Two workshops have been held over the course of this research program. The first one was held at ANLP-NAACL in May of 2000. The Remedia Corpus was distributed to participants ahead of time so that they could each develop and evaluate their own reading comprehension system. Several college-level courses in Natural Language Processing used this task as a class project. During the workshop, participants reported on their systems' design and performance. The second workshop was of a different nature. During this six-week workshop, a collection of researchers from different institutions came together at Johns Hopkins University during the summer of 2000 to build a reading comprehension system. The CBC Corpus discussed earlier was created for this workshop, and the resulting system was called "Spot," who will make an appearance in a later Figure on our teaching environment.

Workshops

- **Workshop on Reading Comprehension Tests as Evaluation for Computer-based Language Understanding Systems**
  - **May 2000 at ANLP-NAACL***
  - **Remedia corpus distributed beforehand; papers reported results**
- **Reading Comprehension Workshop**
  - **Hosted by Johns Hopkins University under NSF funding (www.clsp.jhu.edu/ws2000/groups/reading/), Summer 2000 (six weeks)**
  - **Used the CBC Corpus**
  - **Resulted in system called "Spot"**

* Applied Natural Language Processing / North American Chapter of Association for Computational Linguistics

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Figure 9

HISTORY AND RELATED EFFORTS

While space does not permit a full discussion of all the previous and related work in this area, we do want to mention two efforts that have particular relevance to learning technology. Wendy Lehnert's work deserves special mention because she was one of the first to conduct research in the area of story understanding and question answering based on the story. Her system used sophisticated knowledge representation, reasoning, and inference. While the level of detail that needs to be encoded under this approach can be prohibitive in an open-domain real-world application, it may have applicability in a closed-domain learning scenario. An effort currently underway of particular note is NIST's Question Answering evaluation, which has occurred for the last four years as part of the TREC evaluation. The systems are given a 3gb collection of text and as set of short fact-seeking questions to answer. One central obstacle inherent in this task is that human language allows for many different ways to say the same thing, as shown in the example below.

History and Related Efforts

- Wendy Lehnert (1981): Story understanding and question answering through sophisticated knowledge representation, reasoning, and inferential processing.
  - Requires extensive prior encoding of world knowledge.
- NIST's Text Retrieval Evaluation Conference (TREC) Question Answering Track
  - Given a question and collection of text (3gb), find the answer
  - Problem: many different ways to say the same thing

    ```
    What's the farthest planet from the sun?

        Pluto, the farthest planet from the sun in
        the solar system ...

        Pluto usually is thought of as the ninth
        planet from the sun ...
    ```

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Figure 10

To cope with this complex mapping of form to meaning, many system developers have chosen to utilize the WWW. By providing even more ways of saying the same thing, the WWW gives systems a better chance of finding the answer wording that their system is best able to associate with the question. Once they know what they are looking for, the systems return to the 3gb test corpus to find the answer. The highest ranking system that used this approach got 58% of the 500 questions correct. These results are impressive, but this approach would not be applicable to the reading comprehension task, in which the answer must be drawn from the story at hand.

Fortunately, the most successful approach, taken by LCC, is very relevant to the reading comprehension approach. Their system did not use the WWW as a supplementary source of answers, and instead used lexical knowledge and logical inference -- both ways of addressing the complex mapping of form to meaning. With this approach, 83% of the questions were answered correctly. We at MITRE are encouraged by these results because our current reading comprehension system is built along the same design philosophy. This system, called ABCs, will be discussed below.

History and Related Efforts (cont.)

- **One approach: Use the WWW**
  - **Scored 58% correct and below.**
  - **Won't work for Reading Comprehension task**
    - **Limited to given text passage**
    - **Text can be fiction**
- **Most successful approach: Use lexical knowledge and logical inference**
  - **Moldovan et al. of Language Computer Corporation (LCC)**
  - **Scored 83% correct**

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Figure 11

MITRE'S FIRST READING SYSTEM: DEEP READ

We have built a number of systems over the course of this research program. In this presentation we will show you two of them, the first one and the most recent. The first system, called "Deep Read" (pronounced Deep Red), is also known as the Bag-of-Words approach. It takes the words of each reading comprehension question, identifies the word stems and names of people, places, and organizations, and then puts the words into an unordered set. Next, it identifies the Focus of the question. In the example shown, the Focus is *when* a particular even occurred, so the system knows it's looking for a temporal expression. Next, the system finds sentences in the story whose words overlap with the words in the question "bag." The story has also been processed so that certain expressions like names and dates are flagged; these are shown in blue in the example. The candidate answer sentences are ranked according to which ones have the most word overlap (shown in bold type), and the system then outputs the sentence it thinks contains the answer. (Note that this early system did not return exact answers, but only sentences containing the answer.)
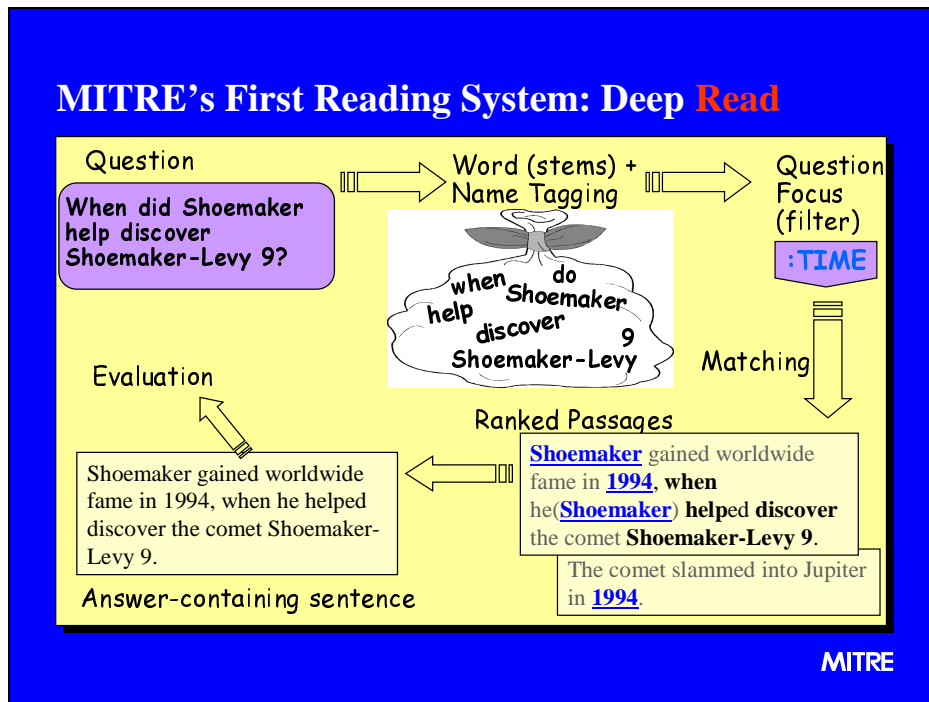
Figure 12

DEEP READ RESULTS ON THE REMEDIA CORPUS

We evaluated Deep Read's performance using the Remedia Corpus. Overall, the system got 34% of the question correct. It performed best on *who*, *what*, and *when* questions, and less well on *where* and *why* questions. We were encouraged by the results of this rudimentary system, one which we built in order to obtain a baseline score. The results indicate that the problem is not trivial, but is tractable.
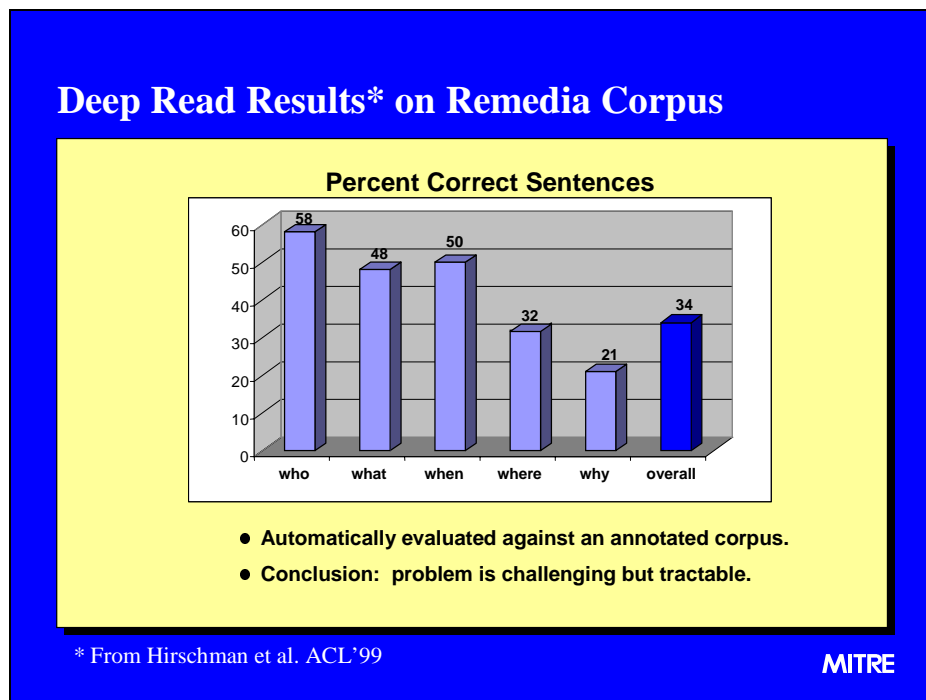
Figure 13

MITRE'S LATEST READING SYSTEM: ABCS

We have taken a very different approach in our most recent system, called the Abduction Based Comprehension system, or ABCs. In creating this system, we had two goals. First, we want to always understand why the system succeeds or fails -- to know what's missing from its design. Second, as we move toward the teaching phase of our research, we want a system that is capable of interacting with a human learner in a meaningful fashion. ABCs thus has a number of characteristics designed to meet these goals. It contains discrete components that can be evaluated independently. It returns exact answer phrases rather than answer sentences and it exploits knowledge sources and even adds to them based on information encountered in the story. ABCs most powerful feature is the logical inference engine, which the system uses to locate and justify answers to the questions. The inference engine gives us access to the system's "thought process," making it more suitable for interacting with a human learner.

MITRE's Latest Reading System: ABCs

Abduction Based Comprehension system

Goals:
- Understand how and why the system succeeds or fails.
- Create a system capable of participating in a learning and teaching environment.

Characteristics:
- Returns exact phrase answers.
- Contains discrete components that can be evaluated independently.
- Exploits knowledge sources, and adds to them.
- Uses a logical inference engine, which allows the system to justify its answers (via a logical proof).
- More natural, intuitive access to the system's "thought processes" makes it better suited for interacting with users.

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Figure 14

ABCS ARCHITECTURE

The example shown here illustrates the information flow through the system. ABCs takes the entire story and sends it through a number of language processors. These processors perform linguistic analyses on the text, including name identification, sentence structure (subject, object, predicate), normalization of temporal expressions, and identification of expressions that refer to the same entity ("co reference"). The questions are processed in the same way. Next, this output goes through a semantic interpretation process to create a set of facts that are added to the Knowledge Base, which also contains existing knowledge in the form of a lexicon. ABCs uses the lexicon to identify word meaning as well as synonyms. The questions undergo a similar process, where they are turned into formal queries with a variable assigned to phrases in the question. The Abductive Proof Procedure then attempts to match phrases in the Knowledge Base to variables in the Query, using abduction where needed. From this, one or more candidate answers are generated. In some cases, the Answer Generator then chooses the best way to present the answer. For example, if the question in this case were "Who helped discover the comet…," the system would first find "he" as the answer since it is the local subject of the verb "helped" in the story. The Answer Generator would look up who "he" refers to, and output "Eugene Shoemaker" as the answer.
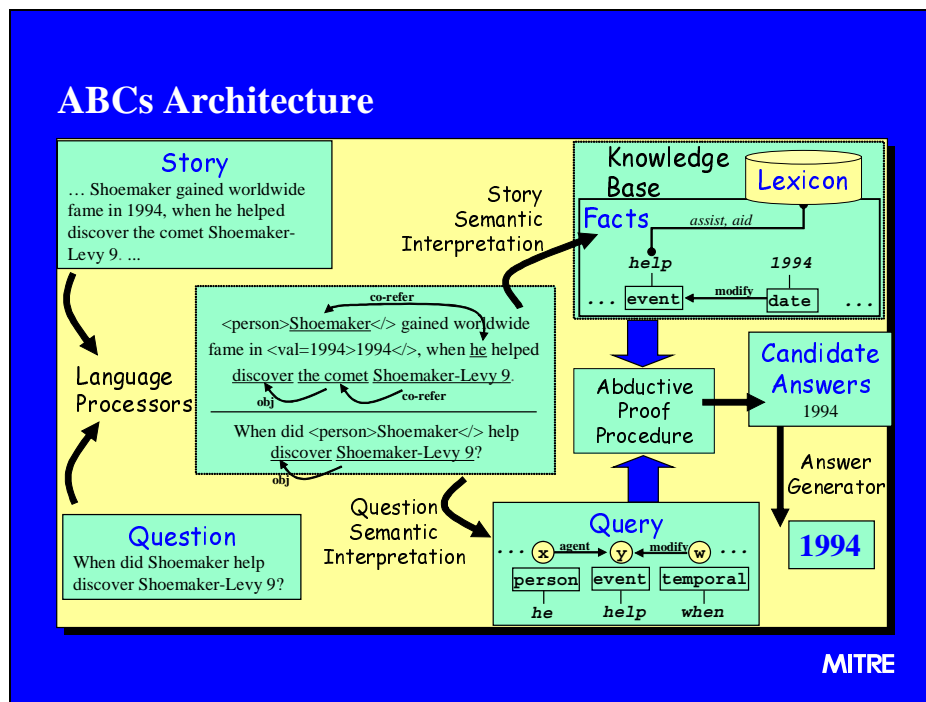
Figure 15

ABCS RESULTS ON THE REMEDIA CORPUS

We recently evaluated the performance of ABCs on the Remedia Corpus. The chart shown here shows the results for two sets data sets: Development and Evaluation (see Figure 6 for a discussion of the different data sets). Although the system performed consistently better on the Development data, the difference is not statistically significant due to the small size of the data sets (30 stories for Development, and 60 stories for Evaluation). Note that these results are not directly comparable to those of Deep Read, because ABCs has not yet been evaluated on *why* questions and ABCs also have the harder task of returning exact answers. These results were obtained by having a human grader evaluate the system's response, using an answer key as a guide. An answer was deemed *inexact* rather than *correct* if the answer was not worded properly; e.g., the system returned "the first woman" instead of "the first woman to fly faster than the speed of sound." Overall, the system answered around 45% of the questions correctly, performing quite well on *who* and *when* questions. *What* questions are particularly difficult; one reason for this is that while the Focus of a *who* question is fairly easy to interpret, the Focus of *what* questions is much more variable. In the near future we plan to build additional components for ABCs, enhance its logical inference process, and evaluate it with additional corpora such as the CBC Corpus.
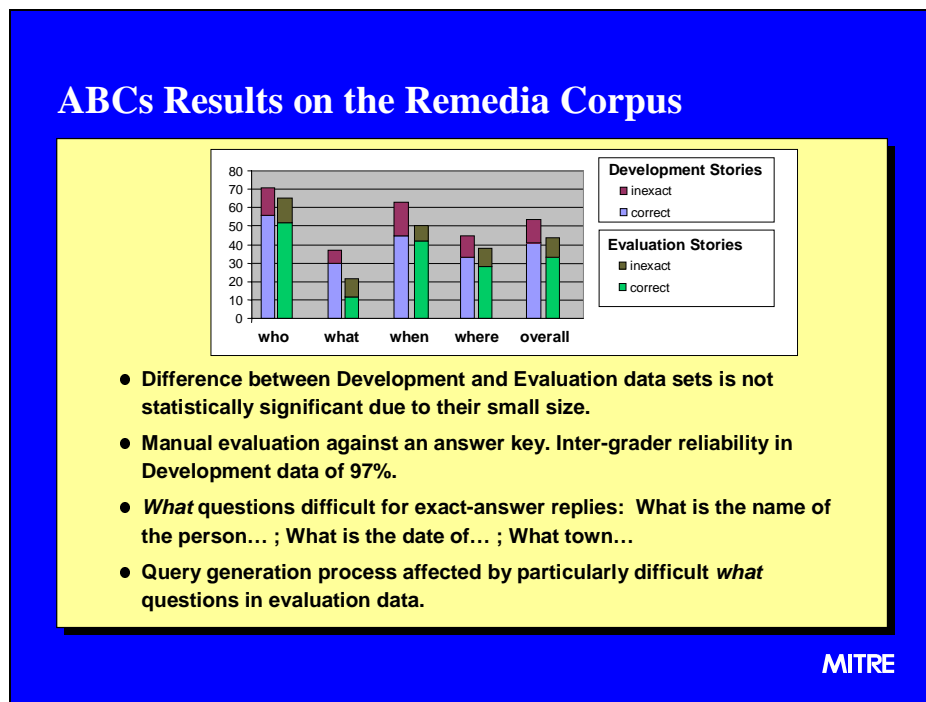
Figure 16

In the second part of this presentation we will discuss the learning environments that could incorporate the reading comprehension systems described earlier. In designing prototype learning environments, we have adopted a technique known as Reciprocal Teaching. Originally designed to teach reading skills to humans, it takes the form of a dialogue about a text between a teacher and a group of students. Everyone takes a turn at leading the dialogue.   As part of the dialogue, participants ask each other reading comprehension question as well as clarification questions.   A large collection empirical research has demonstrated how effective this technique is both for reading skills and other educational domains. Cognitive Apprenticeship is another philosophy that we've embraced while developing ideas for a reading comprehension tutor.   Given this background, our research question has become, "Can a system like ABCs act as a simulated peer learner in a Reciprocal Teaching dialogue?"

Figure 17

CAN THE COMPUTER BE A PEER LEANER?

The diagram shown here sketches how a dialogue might play out between a simulated computer peer and a human student who is leading the dialogue. The human student would first ask a question. Ideally, a subcomponent would evaluate the quality of the students question and guide her in asking questions that will enhance her own understanding of the reading material. The system could then either posit an answer or ask a clarification question. The human student would evaluate the correctness of the system's answer or respond to the system's clarification question. If the human student indicates that the system's answer is wrong, the system can try again, ask a clarification question, or just give up and ask for the answer. Regardless of the outcome, the system benefits by logging the exchange for future training. Under the theory of Reciprocal Teaching, the human student benefits by asking questions about the text -- a very useful comprehension strategy.

Figure 18

179
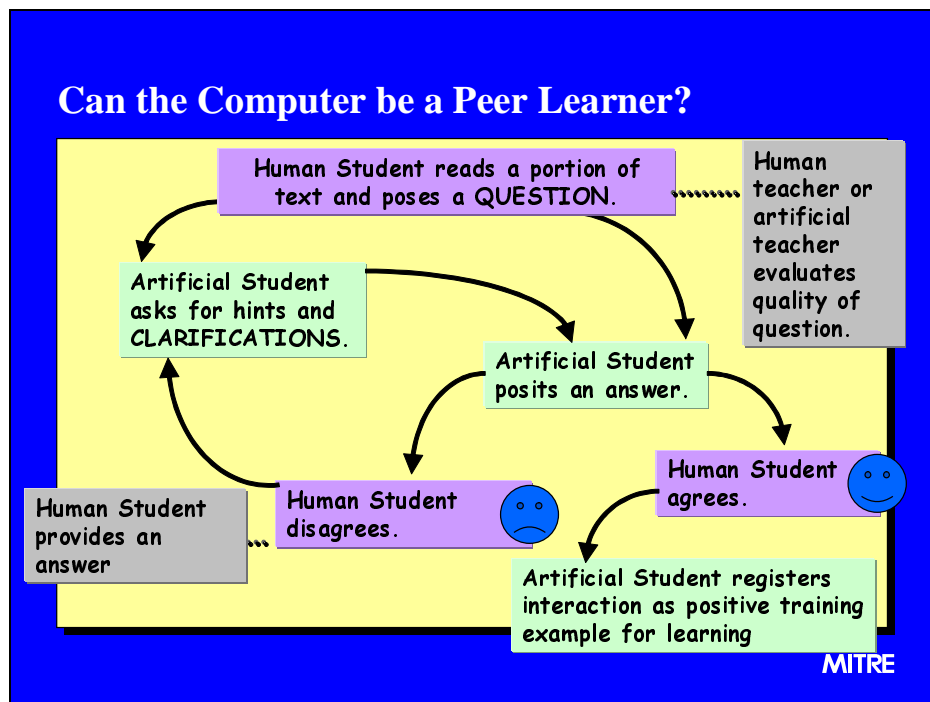
RECIPROCAL TEACHING ENVIRONMENT

We have developed a rudimentary graphical user interface to explore this idea further, and to give us a means to demonstrate to potential collaborators the type of environment we envision. In the left half of the screen is the story that is being read, and in the right half is the history of the dialogue about the story. There are three participants in the dialogue. One is a simulated teacher whose main function is to facilitate the exchange between the other two participants, and also to ask questions of the human student, since our reading comprehension system does not ask questions. The second dialogue participant is the human student, and the third is one of our Reading Comprehension systems, in this case, Spot, mentioned earlier in Figure 8. The first five lines in the dialogue show the human student answering a question presented by the teacher. The teacher's questions come from a stored list of questions. The student's responses are being "graded" by a separate component that compares the answers against an existing answer key. The final four lines of the dialogue show Spot taking a turn at answering the human student's question, which the human then evaluates as correct.
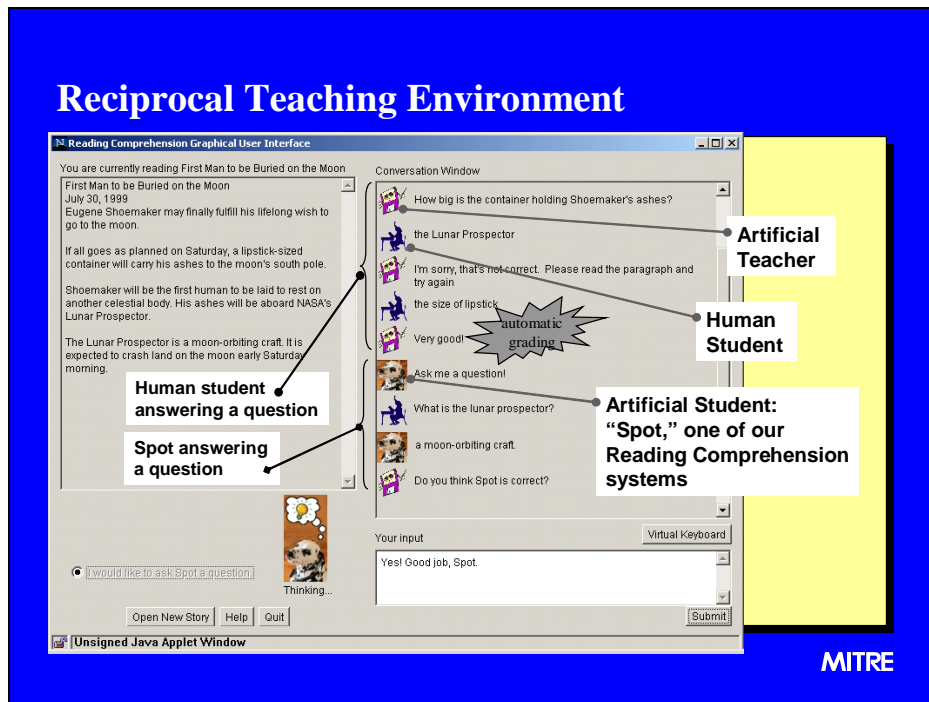
Figure 19

AUTHORING TOOL

As the previous Figure demonstrated, much of the material in this interface can be created in advance by professional courseware developers. To facilitate the creation of stories, questions, and answer keys, an authoring tool would be an essential component of this learning environment. This would give instructors the ability to develop their own materials while at the same time eliminating the need for them to modify the natural language processing technology underlying the software.

Figure 20

CLARIFICATION QUESTIONS FROM ABCS

Earlier we saw Spot answering fact-seeking questions. Another process that Reciprocal Teaching encourages is the asking of clarification questions. Our new ABCs system, with its use of logical reasoning, is able to do just that. In the example below, the story says early on, "Six sailors finished a 5,000-mile sailboat trip yesterday." Later, it states, "The name of their boat is the Kon Tiki." When asked "What is the name of their sailboat?" the system responds with a clarification question "Is [their,boat] an instance of a sailboat?" It is trying to abduce that "their boat" is a sailboat, since the question mentions "their sailboat." Once the user confirms the validity of this abduction, the system posits the answer, "Kon Tiki." This interface was only a couple of weeks old at the time of this writing, and much more would need to be done to make the clarification questions easier to understand, and determine what type of clarification questions would be beneficial for the human student to encounter. Nevertheless, this demonstrates how reasoning-based systems can add a degree of naturalness to simulated peers.

Figure 21

SUMMARY

Natural Language Processing systems are not perfect, and won't be for some time. But there are certain scenarios and teaching philosophies in which the computer does not have to be perfect in order to be a useful participant in a learning environment. In particular, the reading and question-answering component can play the role of a simulated peer, since real peers are not perfect either. This scenario is further enhanced with reasoning-based systems, which can interact with human students in a dynamic dialogue.

Summary

- The computer doesn't have to be perfect to be a good pedagogical tool.
- The computer can play many roles with different components:
  - Teacher
  - Student
  - Grader
- A computer system capable of reasoning and learning can act as a student peer in an interactive learning environment:
  - Asking (and knowing when to ask) clarification questions (e.g., about word meaning) and then remembering and using the feedback to improve performance.
  - Providing justifications for answers.

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Figure 22

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Figure 23

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Figure 24

A Systematic Approach to Research:
Roadmapping Activities by the Learning Federation

Marianne Bakia
Learning Science & Technology
Federation of American Scientists
Washington, DC

A SYSTEMATIC APPROACH TO RESEARCH:
ROADMAPPING ACTIVITIES BY THE LEARNING FEDERATION

This talk will discuss why it is necessary to conduct an inter-industry roadmapping exercise to encourage greater innovation in educational technology development.
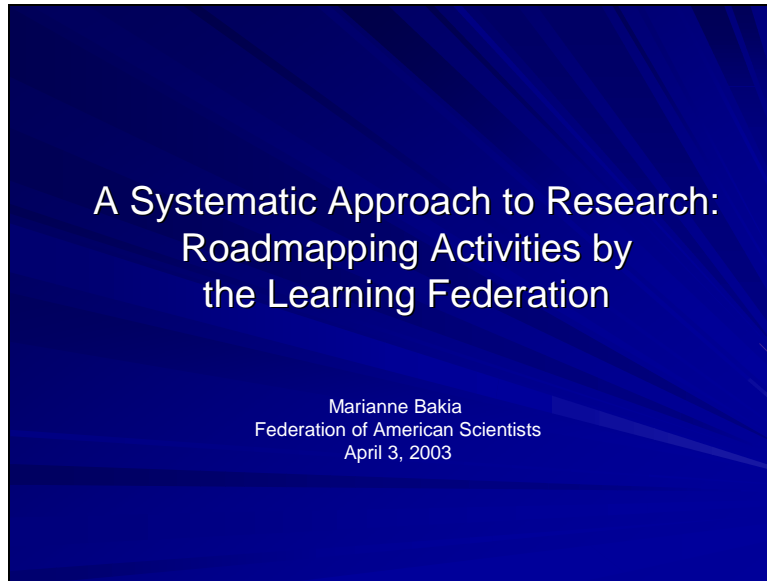
Figure 1
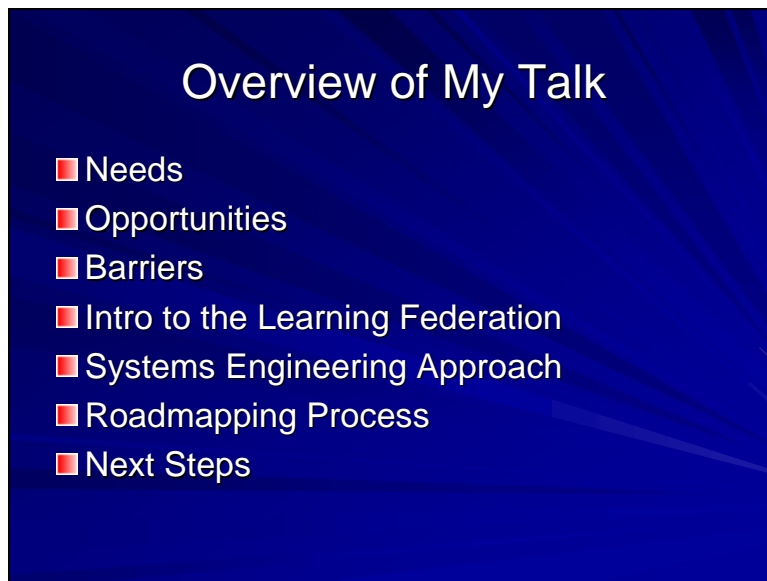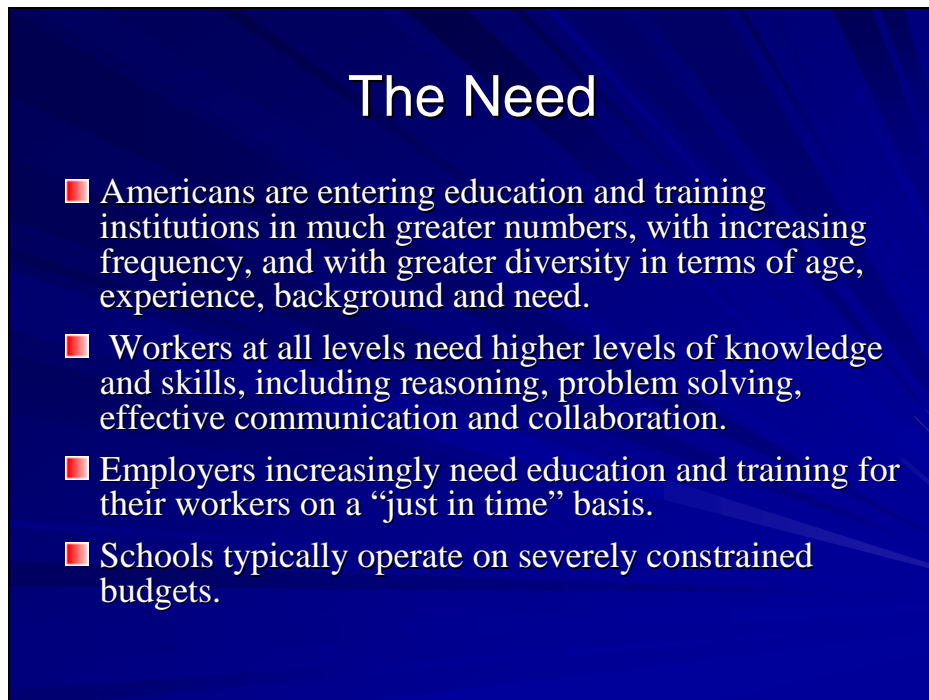
Figure 2

THE NEED

The need to develop more powerful educational technologies is based on a unique confluence of events that include an increase in the number and diversity of students seeking education.   the In addition to serving the new, enlarged student body, education systems are also being asked to emphasize reasoning, problem solving, effective communication and collaboration at all levels of education. These new demands come at a time when education budgets are under tremendous pressure.

Figure 3

THE OPPORTUNITY

There is a wide variety of software-based tools and services being developed for education. These tools facilitate every aspect of the educational process including teaching, learning, and administration. Common applications include a phenomenal increase in access to scholarly and informational sources over the web through digital libraries and related collections. Technology can also improve the teaching of complex knowledge and skills through visualizations, models and simulations. Teaching tools like "intelligent tutoring systems" are also changing teaching norms and improving learning outcomes. Through distributed learning and virtual worlds, students often become more motivated and can apply new knowledge and skills in powerful ways. Learning management tools are also emerging that can lighten the burden placed on teachers to individualize instruction and keep track of administrative information.

The Opportunity

- Large Scale Digital Libraries and Online Museums
- Visualization, Modeling, and Simulation
- Intelligent Tutoring Systems
- Distributed Learning and Collaboration
- Virtual worlds
- Learning management tools
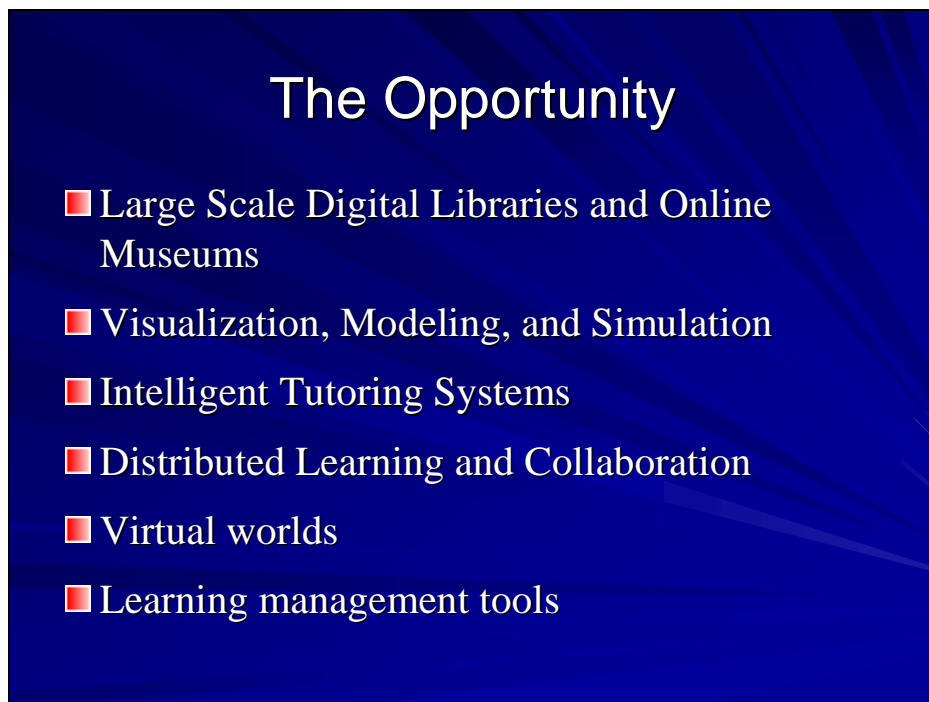
Figure 4

BARRIERS

These applications are still in an early stage of development. Research is needed in an array of areas related to information technology, software design, and the processes of cognition, learning, and memory. Developing an instructional technology may require multidisciplinary effort—both in terms of research and product development

Unfortunately, there are few bridges between cognitive researchers, commercial producers, inventors of learning technologies and commercial product developers, and practitioners. Individual developers are often forced to design every aspect of a system with inadequate resources.

Figure 5

A DRAMATICALLY DIFFERENT APPROACH TO RESEARCH AND DEVELOPMENT IS REQUIRED: THE LEARNING FEDERATION

       If we are to realize the power of technologies to improve education, a dramatically different approach to research and development is required. The Learning Federation has been organized to facilitate this transformation.   We are working to catalyze a revolution in learning.

Figure 6

THE LEARNING FEDERATION

The Learning Federation began with the creation of a SEMATECH-like consortium that includes industry, academia, government, foundations. The first phase of operation includes the development of a research roadmap that includes key priorities for future innovation and details a plan of action to accomplish these goals. The second phase of operation will launch a program that operates at between $100M-$200M/year a year to execute the roadmap. This program will support large-scale, sustained efforts involving multiple disciplines and drawing on expertise from academia, industry, and government laboratories.

Figure 7

LEADERSHIP

The Learning Federation's leadership includes representatives from America's top universities, businesses, and government agencies. Our steering committee includes many leaders from computer science and cognitive science. Microsoft, Hewlett Packard, and the Corporation of Public Broadcasting are founding corporate members.

Leadership

Steering Committee
- Ruzena Bajcsy, UC Berkeley
- John Bransford, Vanderbilt U
- Randy Hinrichs, Microsoft Research
- Ed Lazowska, U Washington
- Elliott Masie, Masie Center
- Richard Newton, UC Berkeley
- Don Norman, Nielsen Norman Group
- Raj Reddy, CMU
- Shankar Sastry, UC Berkeley
- Bill Spencer, Washington Advisory Group
- Janos Sztipanovits, DARPA, Vanderbilt U
- Andries van Dam, Brown U
- Karen Watson, CPB
- Ann Wittbrodt, HP

Executive Management
Henry Kelly, Federation of American Scientists
Marianne Bakia, FAS
Kay Howell, FAS
Tom Kalil, UC Berkeley

Figure 8

LF MISSION

The mission of the Learning Federation is to dramatically increase the funding available for the research and development of educational technologies. We are working closely with the Digital Promise Project (www.digitalpromise.org) to establish a National trust fund for innovation in educational technologies. These funds will be used to encourage a systematic, collaborative approach to research and development. The focus of research and development will be on pre-competitive tool development for next generation technologies.

LF Mission

- To dramatically increase funding for research and development of educational technologies (Digital Promise)

- Encourage a systematic, collaborative approach to research and development

- Focus on pre-competitive R&D for next generation technologies

Figure 9

SYSTEMS ENGINEERING

The Learning Federation's efforts are designed to launch education technology development out of the "cottage industry style" into an industrial mode that allows for interoperable components to be individually developed and sold. The design of environments will be guided by the latest in cognitive research and scientifically-based pedagogical approaches. Tools sets will expand the development of simulations and immersive environments that will help them practice actions and procedures as easily as they can study facts and concepts. Learner modeling and assessment tools will validate teaching processes and help ensure that curriculum is tailored to individual needs. Research shows that feedback and interactivity are important components of any learning system, and tools for question generation and answering as well as more general communications technologies will facilitate these aspects of learning. Integration tools will facilitate the easy connection of the components into specialized learning systems.
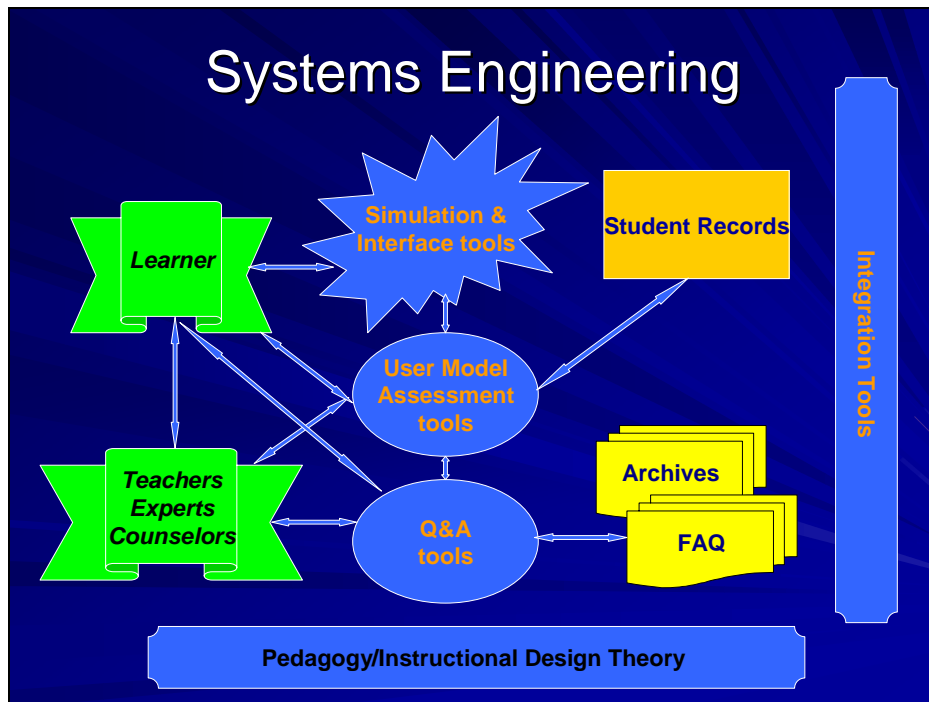
Figure 10

THE LEARNING FEDERATION
LEARNING SCIENCE AND TECHNOLOGY R & D ROADMAP
WORKSHOPS PROJECTS

This figure details the components of the roadmap. A workshop of 40 national experts in relevant areas has been developed for each topic. The instructional design workshop includes cognitive scientists, educational technology developers, and instructional designers. The question generation and answering workshop brought together help-desk operators, linguists, and educational technology developers to highlight best practice and identify continued research needs.

Figure 11

With the current emphasis on testing and accountability in education, new technologies could help create affordable, more robust student assessments. These assessments are also a necessary element of individualizing curriculum to student needs and interests. By monitoring motivation and comprehension, these tools could capture some of the most promising techniques of human tutors, which are too expensive for massive deployment in all educational environments. With key component tools developed, it will also be necessary to have integration tools that can link each of the individual elements into a comprehensive system.

The Learning Federation
Learning Science and Technology R&D
Roadmap Workshops Projects

Assessment Tools for Technology-Enabled Learning Systems - What to Measure, When to Measure, How to Use the Information: The workshop will study how to apply learning science to develop multi-dimensional measures of learners' approaches to expertise in SMET areas of interest. The workshop will identify research priorities for designing and building tools to gather information for assessment, inform software and instructors for efficient management of the learning process, and provide iterative feedback loops. Key topics include:

- Measuring individual and group skills
- Measuring levels of learner interest and motivation in complex environments (including discovery-based learning scenarios)
- Defining useful measures of learning styles and measuring how they may be revealed by student performance
- Embedded, continuous, multi-dimensional assessments of content mastery; embedded systems to discover individual learning styles.
- Programmable tools that use the information gathered to trigger appropriate automated responses in the courseware (active course management) or set alarms to summon teachers/experts
- Ensuring security and privacy of assessment information.
- Management and record keeping including public and private portfolios (available only to learners and their teachers)

Integration Tools for Content and Instructional Design of Technology-Enabled Learning Systems: The workshop will focus on R&D priorities for building tools to translate learning theories into functional learning environments and establish an open process for worldwide collaboration on building and maintaining learning environments. The workshop agenda will focus on:

- Developing course building tools for designing scenarios, creating assignments, designing response to information gathered from student observer tools, and programming avatar behaviors
- Designing tools to allow for easy formation of teams/groups even when members are geographically dispersed (P2P tools, building and managing networks of learners, students, and specialists.)

Figure 12

THE ROADMAP PROCESS

The research roadmap is the plan that will guide this development process. The roadmap is being developed in multiple stages. First, we organized a workshop of the nation's leading experts in learning technologies to identify principal research areas. Next, we developed research priorities within research area that was identified. We developed a strawman outline with key headings, goals and research tasks, which was revised based on literature reviews, interviews with experts. In a series of workshops, we have solicited peer review of roadmap components. These components will be integrated into a final report. The report will be used to launch the necessary research. Because planning is a continuous process, we will be repeating the roadmapping process on a regular basis.

Figure 13

THE LEARNING FEDERATION ROADMAP WORKSHOPS PROJECTS

The Learning Federation is in the process of completing the first phase of operation. Workshops have been completed, and we are in the process of finalizing component roadmaps.

The Learning Federation Roadmap Workshops Projects

Workshop Description	Preparation Status	Date/Location Workshops
Question Generation and Answering Systems for Technology-Enabled Learning Systems	- preliminary roadmap published and disseminated for review & comment - workshop to produce final roadmap announced and invitations sent	Oct. 4 & 5 2002 at Univ. of Memphis to develop preliminary roadmap April 10 & 11 at MITRE Bedford, MA to develop final roadmap
Instructional Design for New Technology-Enabled Approaches to Learning	- Industry visits in progress - Draft roadmap in progress	December 4 &5 2002 at Univ. Central Florida Simulation Center, Orlando FL
Assessment Tools for Technology-Enabled Learning Systems	- Planning in progress	May 4 – 6, 2003 Seattle, WA
Virtual Environments to Support Exploration-Based Pedagogy • Next Generation Approaches for the Geometrical Modeling and Dynamic Simulation of Biological Systems	- workshop report in progress - Planning for Workshop op Navigation Tools in progress	- Geometrical Modeling workshop held January 25 2003 Newport Beach, CA (in conjunction with the Medicine Meets VR Conference)
Integration Tools for Content and Instructional Design of Technology-Enabled Learning Systems	- Focus topics identified	TBD
Integrated Roadmap	-looming on the horizon	July 2003 at IDA Washington, DC

Figure 14

NEXT STEPS

Once we have completed the roadmap in August, we will launch a public campaign to communicate the need for increased public investment through the fall of 2003. This campaign will include constituent outreach with researchers, developers and practitioners.

Figure 15

Figure 16

Intelligent Agents for Distance Learning

Brad Goodman
The MITRE Corporation
Bedford, MA

INTELLIGENT AGENTS FOR DISTANCE LEARNING

Our research project is exploring techniques for providing stimulating peer learning experiences in web-based, collaborative distance-learning environments. We are leveraging intelligent tutoring system and collaborative learning technologies to develop an artificial learning agent to collaborate with human peers. The agent will follow the discussion and interact with the participants when it detects learning trouble of some sort, such as confusion about the problem they are working on or a participant who is dominating the discussion or not interacting with the other participants. In order to recognize problems in the dialogue, we are first examining the role that a participant is playing as the dialogue progresses. This simulated peer will play supportive roles based on the instructional needs of the human learners. This talk describes our pursuit of indicators for effective and ineffective collaborative learning. Potential indicators such as communicative acts, participant roles, and other conversational elements will be discussed. This project builds on a collaborative-learning infrastructure developed in a previous MITRE research project to bridge distance and time barriers between on-line learners [8, 19, 21].

OVERVIEW

This talk will introduce the training issues that led up to this research. Background to motivate the research will be given. Research problems will be presented. The area of collaborative dialogue modeling will be introduced. A description of the analytical techniques employed in this research to predict when instructional intervention was required is presented. Lastly, a description of an intelligent agent peer that is under construction will be given.

Overview

- Introduction
- Research Motivation
- Research Problems
- Collaborative Dialogue Modeling
- Protocol Analysis for Intervention Prediction
- Pierce, An Intelligent Agent Peer

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Figure 1

PROBLEM

Soldiers face conflicts in a rapidly changing world. These conflicts cannot be fully anticipated when training is developed for the schoolhouse. Therefore soldiers must adapt on the fly to ill-defined battlefield situations applying what they have learned & reasoning about the situation at hand. Relying on schoolhouse solutions won't work.

Classroom learning improves considerably when students participate in structured learning activities with small groups of peers [2]. Peers can encourage each other to reflect on what they are learning and to articulate their thinking, which enhances the learning process [5]. Reflective activities, such as After Action Reviews in military exercises, encourage students to analyze their performance, contrast their actions to those of others, abstract the actions they used in similar situations, and compare their actions to those of novices and experts [5, 13].
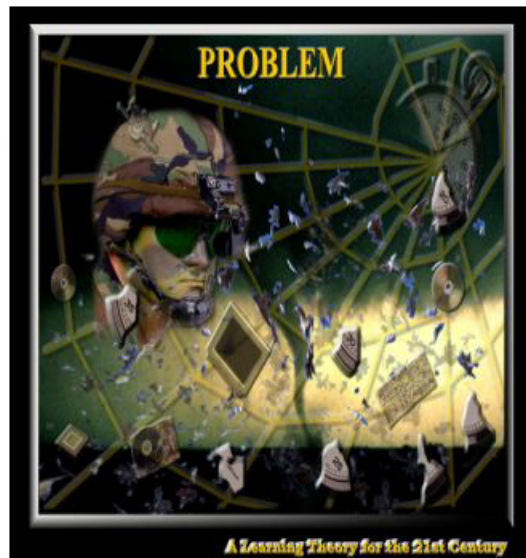
Figure 2

BACKGROUND

Our work is an outgrowth of research in both the intelligent tutoring system and collaborative learning communities [13]. We first developed a simulated learning companion capable of acting as a peer in an intelligent tutoring system [4, 7]. The presence of the learning companion can help ensure the availability of a capable collaborator to enrich learning through the promotion of reflection and articulation in the human student. In other work on distance learning, a student is allowed to work with students in other locations through a collaborative system [8, 13, 17].

Our current work is attempting to combine these approaches by allowing students to work both with a collaborative system and with an electronic peer. The overall goal is to provide an electronic peer that can co-exist in cyberspace with human collaborators and interact as a partner to promote effective collaborative learning and problem solving. The peer monitors the discussion and interacts with the participants when it detects learning trouble of some sort, such as confusion about the problem they are working on, or a participant who is dominating the discussion or not interacting with others.
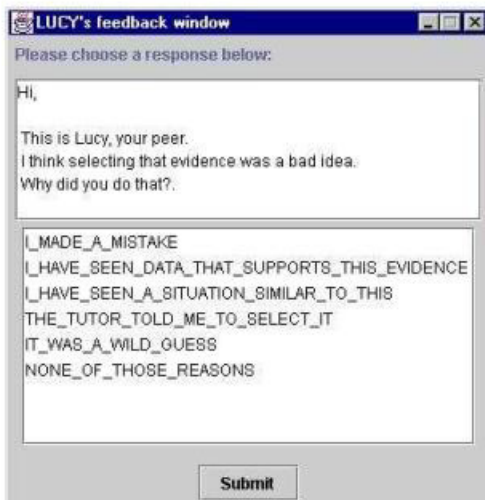
Figure 3

The current focus of our work is on automatically detecting such learning problems. The actions of participants, with respect to chat and workspace tools, provide an initial indicator of discussion and progress towards completing an assigned task or dealing with an obstacle. The roles of participants can provide a secondary indicator. We will discuss our use of participant roles as indicators of group activity, how we determine them statistically, and our plans for moving on to the next step.

Figure 4

SET A BASELINE: COOPERATIVE PROBLEM SOLVING

Our research in learning companions motivated us to investigate collaborative learning among students more closely. We studied the dynamics of collaborative learning groups [19, 21] by observing students working together to solve a common problem. The study was conducted during a five-day course in which students learned and used a software design methodology, Object Modeling Technique (OMT), to collaboratively design software systems. The students were videotaped as they worked in groups of four or five. The videotape transcriptions were coded with a conversational act-based coding scheme, and studied using summary and sequential analysis techniques. We found that students learning in small groups encourage each other to ask questions, explain and justify their opinions, articulate their reasoning, and elaborate and reflect upon their knowledge, thereby motivating and improving learning.

Figure 5

A FIRST STEP TOWARDS AN INTELLIGENT AGENT PEER

We followed our initial study with the development of a collaborative learning environment for OMT. Our goal was to provide a web-based environment that would permit us to analyze peer-to-peer dialogue and tool actions in an attempt to identify the strength and weaknesses of a group's interaction. As part of that study, we looked for indicators that the learning process was in trouble.

Figure 6

DRIVING AN INTELLIGENT AGENT

The actions of an intelligent agent in a collaborative learning context could be governed by peer-like behavior, pedagogical behavior, and group dynamics. Peer-like behavior can be derived from traditional intelligent tutoring system research. Expert knowledge about the domain under instruction and typical student misconceptions can delineate the information the agent should convey. How that information is presented to the student is based on typical pedagogical behavior in a collaborative instructional situation. Instructional principles and available instructional resources will determine what behavior should be exhibited by the intelligent agent. Lastly, group dynamics plays an important role in determining how to structure the interaction between the agent and the students. The effectiveness of communication between the students can be examined and, where necessary, improved. The agent can assume a missing role to help improve group interaction.

Driving an Intelligent Agent

- **Peer-like behavior**
  - Expert knowledge
  - Misconceptions
- **Pedagogical behavior**
  - Instructional principles
  - Instructional resources
- **Group dynamics**
  - Communicative effectiveness
  - Role playing

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Figure 7

PLANNING AGENT ACTIONS

       The actions of the intelligent agent must be carefully planned to cover the issues outlined in the last slide. A planning component would need to answer a set of questions about the group interaction and the instructional needs to best help facilitate learning.

Figure 8

GOAL: PROMOTE IMPROVED GROUP DYNAMICS FOR LEARNING

Small group dynamics research can benefit collaborative learning. The promotion of more effective interaction in a group can increase the learning of the group and its members. Students learning in small groups encourage each other to ask questions, explain and justify their opinions, articulate their reasoning, and elaborate and reflect upon their knowledge, thereby motivating and improving learning. These benefits, however, are only achieved by active and well-functioning learning teams. Placing students in a group and assigning them a task does not guarantee that the students will engage in effective collaborative learning behavior. While some peer groups seem to interact naturally, others struggle to maintain a balance of participation, leadership, understanding, and encouragement. Traditional lecture-oriented classrooms do not teach students the social skills they need to interact effectively in a team, and few students involved in team projects or exposed to integrated working environments learn these skills well.

Figure 9

PREDICTING EFFECTIVENESS

We followed our initial study with the development of a collaborative learning environment for OMT. Our goal was to provide a web-based environment that would permit us to analyze peer-to-peer dialogue and tool actions in an attempt to identify the strength and weaknesses of a group's interaction. The collaborative environment employed a sentence opener-based chat interface [16] and a shared OMT workspace tool. The sentence-opener interface allowed the conversational act underlying each student utterance to be logged; the shared OMT workspace tool permitted student tool actions to be recorded. We ran an experiment in which groups of three subjects used our collaborative environment to solve a software design problem with OMT. The results of our experiment [19, 21] demonstrate the potential of conversational acts to identify, for example, the distinction between a balanced, supportive group and an unbalanced, unsupportive group. Participant roles in dialogue provide another indication of group effectiveness. We are trying to identify problem-solving roles portrayed by the group members during the session to see if they might indicate progress or lack thereof towards successfully completing the exercise. This undertaking entails examining the relationship between conversational acts and problem-solving roles.

Figure 10

213

The current focus of our work is on automatically detecting when trouble appears during group problem solving. The actions of participants, with respect to chat and workspace tools, provide an initial indicator of discussion and progress towards completing an assigned task or dealing with an obstacle. The roles of participants can provide a secondary indicator.

Predicting Trouble

■ **What does it mean to say that the learning process is in trouble?**

    – **Are the participants having difficulty solving the problem? How can we tell?**

    – **Is someone talking too much and taking control?**

    – **Is someone talking too little and therefore not engaging in the learning process?**

    – **Is someone never initiating actions, only following suggestions?**

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Figure 11

HYPOTHESIS: PARTICIPANT ROLES CAN HELP US RECOGNIZE PROBLEMS

Our goal in this research was to conduct an experiment to reveal the ways participants in a collaborative learning task interact and the factors that govern those interactions. We wanted to see if (1) the instructional roles played by members of the group could be deduced from machine-inferable factors about the collaboration and (2) whether the presence or absence of particular instructional roles indicated the effectiveness of the learning. Our hypothesis is that the presence or absence of particular roles is a powerful indicator of the status of the on-going learning process. The work we describe here outlines the data we are collecting on the collaboration and the role identification model we are constructing.

Figure 12

THE ROLES

We chose a set of roles developed by Benne and Sheats [1], and modified them slightly to suit the type of dialogues our system elicits, i.e., dialogues involving the use of a whiteboard and a problem-solving task.

The roles

- INITIATOR ("Let's do X.")
- SUGGESTER ("Let's do it this way.")
- EVALUATOR (agree, disagree)
- OK/YES (simple acceptance)
- INFO-SEEKER/INFO-GIVER (questions, answers)
- CONSULTER ("Is this ok?")
- SUPPORTER ("That was great!")
- COORDINATOR ("Bob, why don't you do this.")
- SUMMARIZER ("Here's what we've done so far.")
- DRAWER

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Figure 13

STEP 1: RECOGNIZING ROLES

Dialogues were collected at the University of Pittsburgh and the MITRE Corporation to provide a corpus for study. We examined the data from five groups of University of Pittsburgh [20] and MITRE subjects [9]. Each group had three subjects. The subjects were paid undergraduates and MITRE employees. We coded the data with participant roles. This analysis led us to tracking the roles of participants during a problem solving session. The next portion of our talk describes our approach towards detecting underlying participant roles. In particular, we present here a discussion of classification and regression tree (CART) models for recognizing roles and what we have learned so far.

Figure 14

CART MODELS

CART models are binary decision trees that can build statistical models from feature values. They take a series of input feature values and use them to predict another feature value. We use a set of features that describe the utterances in our dialogues to predict the role that the participants are playing. We chose a series of input feature values that were either captured by the system or derived from some shallow processing on the utterances. The features we find most useful for predicting roles at this stage store information concerning the general category of each utterance (a high-level conversational act), the specific subcategory into which the utterance falls (a more specific conversational act) and the person who made the utterance. For example, the general utterance category includes *Request*, which includes subcategories such as *Request-Attention* and *Request-Action*, and the category *Motivate*, which includes subcategories such as *Encourage* and *Agree*.

CART models

- **CART models: binary decision trees**
  - Given a set of feature-value pairs they predict one value, in this case the role
- **Inputs to the CART model (feature-value pairs)**
  - Communicative act type (automatically annotated by sentence-opener buttons)
    - General communicative act category: Motivate, Request, Inform
    - Communicative act subcategory: Offer-Alternative, Clarification, Elaborate
  - Who the speaker is, who the previous few speakers were
  - Shallow text processing

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Figure 15

This diagram shows the top of the CART model. Within the top portion of the tree, the CART model shows how it decides between the most easily recognizable categories, such as when the person is drawing rather than typing, and when the person is thanking someone or simply saying "Ok." The "move cat" is the general category of the utterance, "move subcat" is the more specific subcategory and the roles are in all capitals. Each nonterminal node of the tree represents a question. If the answer is "yes" then the questioning continues down the left branch of the tree, if "no" then down the right branch, and either a role is chosen for that utterance or another question is asked until a role is finally assigned.
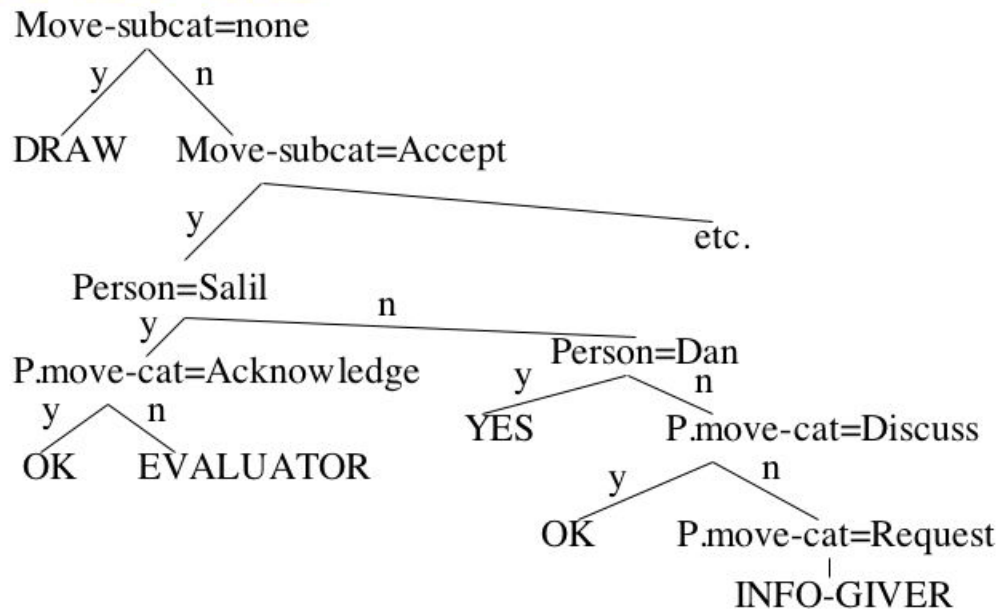
Figure 16

THE CART MODEL – DEEPER INTO THE TREE

       This diagram shows the CART model deeper into the tree. The tree shows how the main category of the utterance and its subcategory can indicate the role being played. Here we see particular roles, such as ELABORATOR or EVALUATOR, being determined.
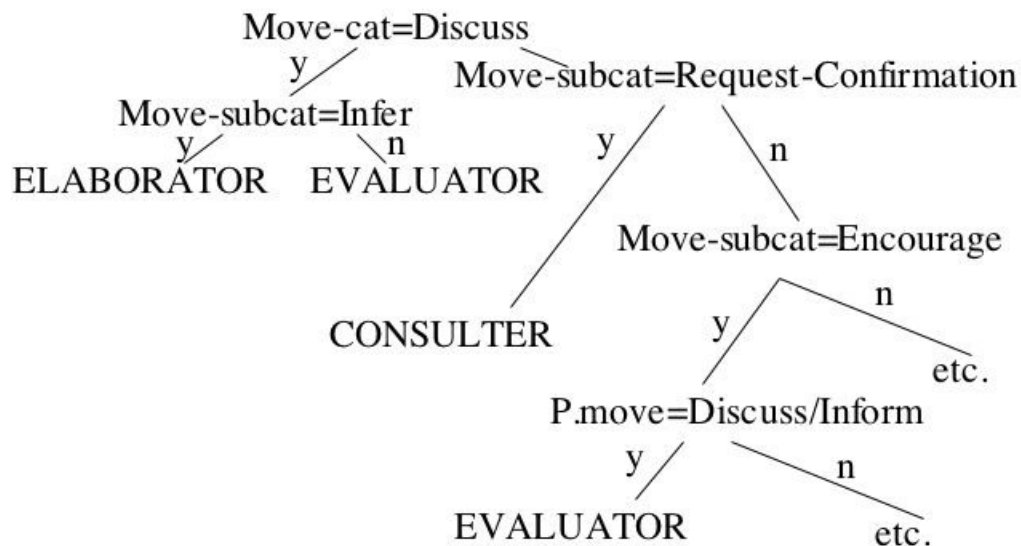
Figure 17

RESULTS

We are using 4-fold cross-validation with the Festival Speech Synthesis System's CART-model building program, **wagon** (http://www.cstr.ed.ac.uk/projects/festival/), to determine the parameters for the CART model which best predict the participants' roles. At the moment, we do not have a large enough corpus of dialogues to decide which CART model we will ultimately use in our system. While we continue to gather dialogues, we are using these models to give us an initial indication of whether we can predict roles. The indicators look good: Our ability to predict roles on unseen data is 81.5%.

Results
- 4-fold cross-validation study
- Produced 64 CART models per choice of feature set
- Eliminated nonsensical models
  - e.g., Bill is current speaker and Mary spoke 4 utterances ago => INITIATOR (??)
- Chose the best model from the rest
  - avoid overfitting
  - pay attention to results on unseen data
- The best tree for this data gives us 80.3% accuracy in role prediction
  - The features it considers important are the current and previous move category, current move subcategory, and person speaking
  - Underfitting: 76.1% on training.

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Figure 18

CLASSIFYING INTERACTION

Now that we have defined potential input features for an intelligent agent to consider when following the students' dialogue, we need to consider triggers for intervention. This leads us to the problem of recognizing intervention points where the peer should interrupt and interact with the students. Our next step is to build a classifier that predicts group interaction problems in the dialogue, which means annotating the dialogues for different types of problems and using the role and conversational act information to predict the occurrence of a problem. The classifier must have information concerning sequences of roles played by an individual and series of consecutive roles played by all the participants. An initial classifier has been developed using a rule-based reasoning engine and trainable analysis tools.

Classifying Interaction

- Apply results from small group dynamics
  - Roles exhibited by participants
  - Balanced participation
- Derive classifier from experiment data

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Figure 19

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STEP 2: DETERMINING INTERVENTION WITH CONVERSATIONAL ACTS/ROLES

We followed the experimental approach Soller used in her dissertation research[20]. However, instead of coding knowledge sharing segments, we coded segments of good/poor collaboration. Our dialogue segments were often much shorter than Soller's segments (we allowed exchanges as few as five utterances). This led to poorer results. However, we had to work within these tight constraints since a simulated peer cannot help a group if it does not respond soon after a problematic dialogue sequence - detecting and reacting to trouble long after it occurred would only lead to more trouble!

Figure 20

DETERMINING INTERVENTION (CONTINUED)

We developed two HMMs – one that determined whether a particular sequence of communicative/speech acts likely represented "Good Collaboration" and another one that determined whether the sequence was most likely an example of "Poor Collaboration." The HMMs were trained from a portion of the data we collected and coded. Our test set included 11 Good Collaboration and 3 Poor Collaboration segments. One Good segment was incorrectly classified as a Poor segment and two Poor segments were incorrectly classified as Good segments. These results were not encouraging.
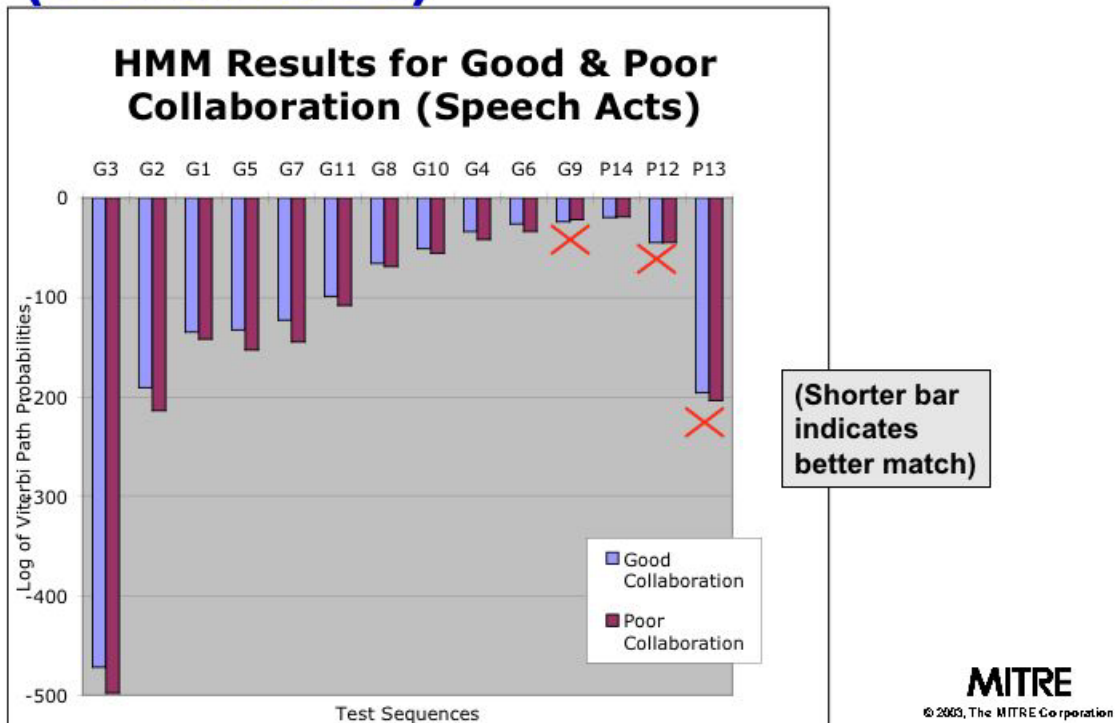
Figure 21

DETERMINING INTERVENTION (CONTINUED)

We developed two more HMMs – one that determined whether a particular sequence of participant roles likely represented "Good Collaboration" and another one that determined whether the sequence was most likely an example of "Poor Collaboration." The HMMs were trained from a portion of the data we collected and coded. Our test set included 11 Good Collaboration and 3 Poor Collaboration segments. Two Poor segments were incorrectly classified as Good segments. These results were again not encouraging.
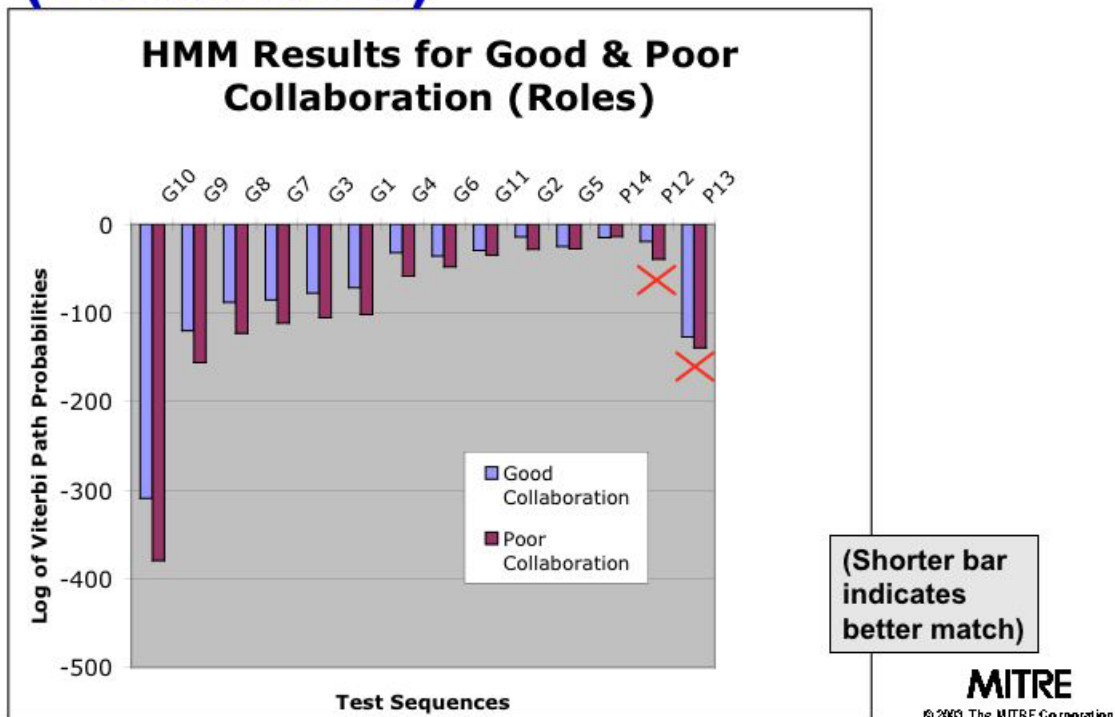
Figure 22

Our HMM classifier results were inconclusive. The number of Good collaboration examples dominated the dialogue segments; too few Poor collaboration examples were available to develop a reasonable HMM. Without gathering many more dialogues, or revising our experiment to "promote" more examples of Poor collaboration, we are forced to drop HMMs as a means for distinguishing Good from Poor collaboration. Instead, we determined three actions to address our problem. (1) The recommendations from the HMMs are to be only one of many inputs to a rule-based reasoning engine that determines when our intelligent peer agent should intervene. (2) Other machine learning techniques such as neural nets should be considered. We are working currently with neural nets. (3) Instead of trying to classify a dialogue segment as simply 'Good' or 'Poor,' it makes sense to look for very specific examples of collaboration. For example, if a student has given an utterance that needs to be replied to or acknowledged, but the utterance is ignored, then that indicates potential poor collaboration. We have developed a neural net that has been able to detect this situation with a good level of accuracy.

Figure 23

STEP 3: PREDICT INTERVENTION WITH CONVERSATION ELEMENTS

Other conversation elements can contribute to the prediction of whether or not intervention is required. We looked at group agreement and disagreement, potential indicators of confusion, discussion topics, and comparison of the students' evolving solution to the expert's solution.

Figure 24

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STEP 4: INTERVENE WITH PIERCE – AN INTELLIGENT PEER AGENT

We developed an intelligent peer agent, Pierce, and added it to our collaborative learning environment. Pierce can observe up to three students working collaboratively over a network on a software design problem. Pierce can look for potential problems and attempt to intervene.
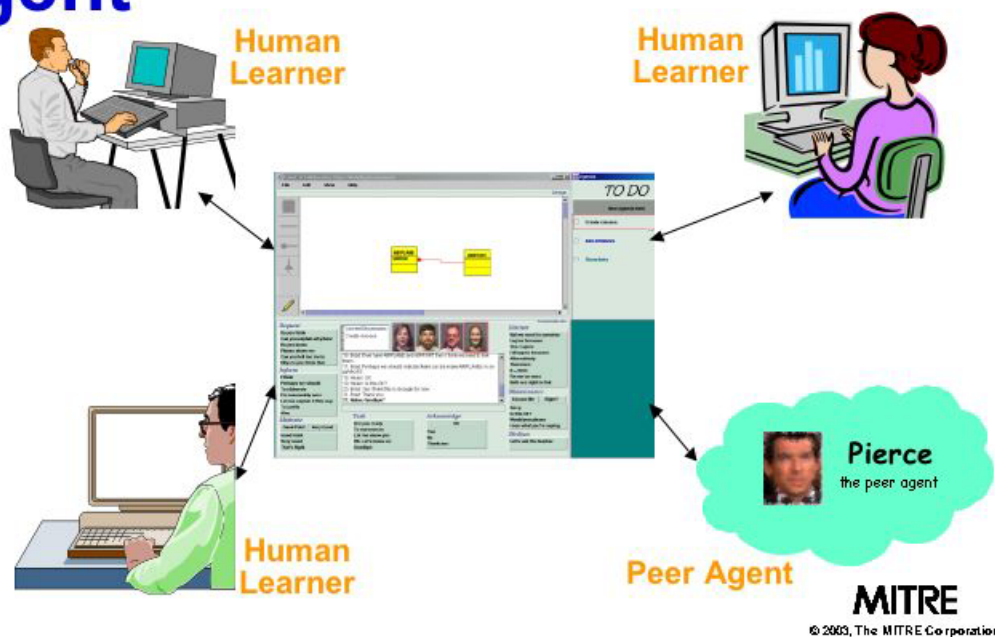
Figure 25

EPSILON STUDENT INTERFACE

We are using Soller's modified version [20] of our collaborative learning interface that she originally developed for us at MITRE [19, 21]. We collected dialogues using Soller's experimental procedures so we could each share the data. Our focus was not on knowledge sharing, however, but instead about looking for patterns of good or poor collaboration. The system provides a sentence-opener chat interface, an OMT workspace, and a new agenda tool. The agenda tool lists high-level goals to be achieved.

Figure 26

AGENT DESIGN REQUIREMENTS

       Our agent had to satisfy a set of design requirements based on the Epsilon architecture as well as the mode of operation desired for real-time interaction with human students. We also wanted the agent's design to be flexible since we wanted the agent to be usable in other collaborative environments.

Agent Design Requirements

- The agent must interface with NCSA's Habanero and the MITRE/LRDC Epsilon collaboration tool, but remain flexible for future integration with other collaborative environments.

- The agent must operate in real time and receive continuous updates from the dialogue, reaching conclusions and sending feedback to the participants on the fly.

- The collaborative analysis should remain domain independent where possible, with space to easily include domain specific information when helpful.

- The architecture must be able to interface with and make use of many types of analysis tools, allowing a combination of AI techniques to be brought to bear on the problem.

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Figure 27

PEER AGENT ARCHITECTURE

An initial classifier has been developed using a rule-based reasoning engine and trainable analysis tools. A reasoning manager controls the flow of information to the trainable analysis tools and the reasoning engine. Student actions, both text chat and drawing commands, are observed. Underlying raw data such as the communicative act, duration of an utterance, time between utterances, and draw object are captured by the agent. The agent translates the event information into a computationally useful format, called a "fact." The translated facts are passed to the reasoning manager and the analytical tools. The analytical tools crunch the data and provide the reasoning manager with additional facts. The reasoning manager sends the facts to the relevant reasoning engines. Each reasoning engine fires rules in an attempt to reach a conclusion. Conclusions are passed to the agent, which if it desires, reacts by executing text chat or drawing commands.

Figure 28

OUTLINE OF ACTION

When the reasoning engine fires a combination of rules that indicate an intervention is useful, it informs the agent. The agent sends text chat or drawing commands into Epsilon, as if it were a human peer, generating an intervention event. The dialogue box illustrates an example intervention.

Outline of Action

- **If the reasoning engine fires a combination of rules that indicate an intervention is useful, it informs the agent**

- **The agent sends commands into Epsilon, generating an intervention event**

> well.
> 51. Milhouse : If we all have same, then your PERSON has name, age, employer 1 ID
> **52. Pierce : Excuse me, Milhouse, but I think you might be confused. You should ask for help on this topic.**
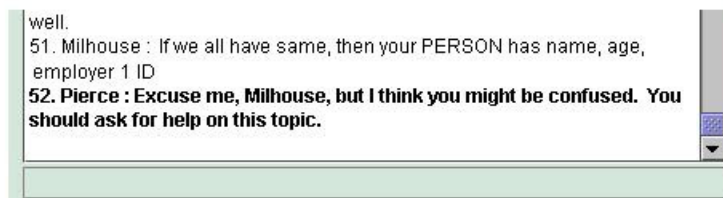
Figure 29

AGENT'S STUDENT MODEL DISPLAY: AGREEMENT, CERTAINTY & PROGRESS

Some of the information captured by the system about individual and group progress can be fed back to the students through a set of gauges. The gauges provide a snapshot of the agent's current estimation of the group's and each student's performance. They measure Certainty, Agreement, Percentage of Task Completed, and Dialogue Speed. A graph of these variables over time is also available.

Snapshot of Agent's current estimation of the group's performance
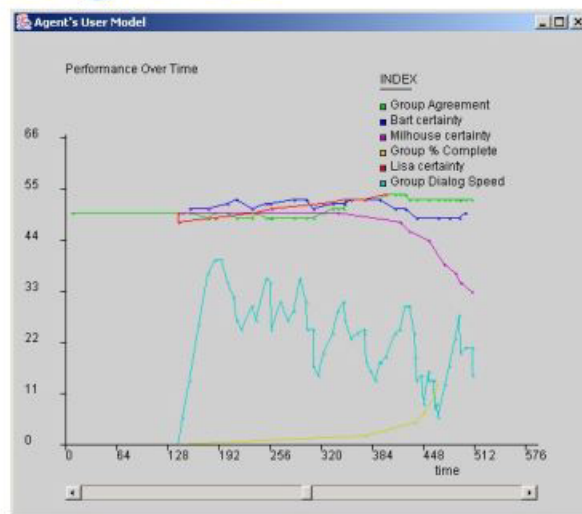
Graph of group performance variables as they change over time

Figure 30

FUTURE DIRECTIONS FOR PIERCE

We are currently refining our intervention reasoner to more accurately determine points of intervention. We are looking at other trainable analysis techniques such as neural nets to process the raw event data. We are considering other features of the collaborative interaction as indicators. Once we have constructed a method for automatically predicting a group interaction problem in the dialogue and the type of problem, we will address as our next issue the type of response most useful for the electronic peer to take. Group interaction roles often seen in well functioning groups but absent in a particular situation are candidate roles for the peer to assume as it responds to the group's needs.

Figure 31

CONCLUDING REMARKS

Our previous and Soller and Lesgold's current research investigates the communication among human participants jointly working on a problem in a collaborative learning environment. The research provides a handle on determining the effectiveness of collaborative discourse on a learner. The communication between collaborators is key to revealing the depth and level of understanding of the instructional domain by the group as a whole and the individual group members. Since natural language understanding is an on-going area of research, our work avoids full understanding of the discourse and instead employs a sentence-opener interface to provide a limited representation of each utterance by its underlying conversational act. Our earlier research, thus, only addresses modeling the collaborative discourse. It says nothing about when or how a peer or tutor should intervene to assist collaborators. Our current research takes this work to the next level – helping determine what is needed to make the collaborative interaction more effective for learning.

Concluding Remarks

- **Getting a handle on peer communication is critical to supporting learning and problem solving in a collaborative environment.**

- **Peer-to-peer interaction promotes learning.**

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Figure 32

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Systematically Designing Pedagogical Agents: Effects of Image, Animation, and Agent Role on Learner Performance and Motivation[1]

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RESEARCH AREAS

      This presentation provides an overview of the PALS (Pedagogical Agent Learning Systems) research agenda regarding pedagogical agent features: image, animation, and role. Each of these three areas is investigated using controlled experimental studies with large sample sizes. Our recent work in each of these areas, as well as our immediate future plans, will be discussed.

Figure 1

First, in the area of pedagogical agent image, we are currently conducting a large scale study to investigate the effects of agent image on learning and motivation. The 3-factor between-subjects design (2x2x2) looks at the impact of agent image in terms of gender, ethnicity, and realism. Each image was created from the same basic template figure as a way to control for basic features, and each was validated to not be significantly different from the others in terms of learner perception (e.g., attractiveness, likableness, etc.) In this study, learners were presented with one of the 8 agents within the learning environment to determine effect on learning and motivation. We are also interested to see post-hoc whether the learners' gender and ethnicity are related to which agent character s/he learns best from. A second study was also recently conducted where learners were presented with *all* of the images and asked to choose which one they would most like to learn from. Results from both of these studies will be available soon.
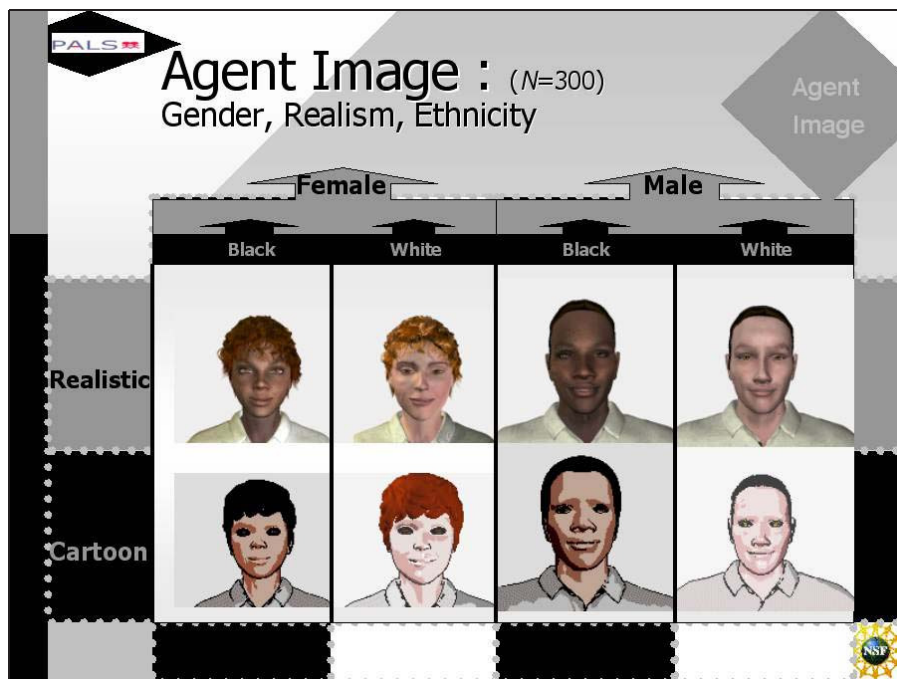
Figure 2

CONTRAST COMPARISONS

In terms of how the agent is *perceived* as person-like, we conducted a study with 75 participants to isolate the impact of image presence/absence and animation presence/absence [11]. Results of the study indicated that the presence of animation with the pedagogical agent was desirable for all related persona measures (as listed below) and particularly for "instructor-like," which is of the most interest in a learning environment.
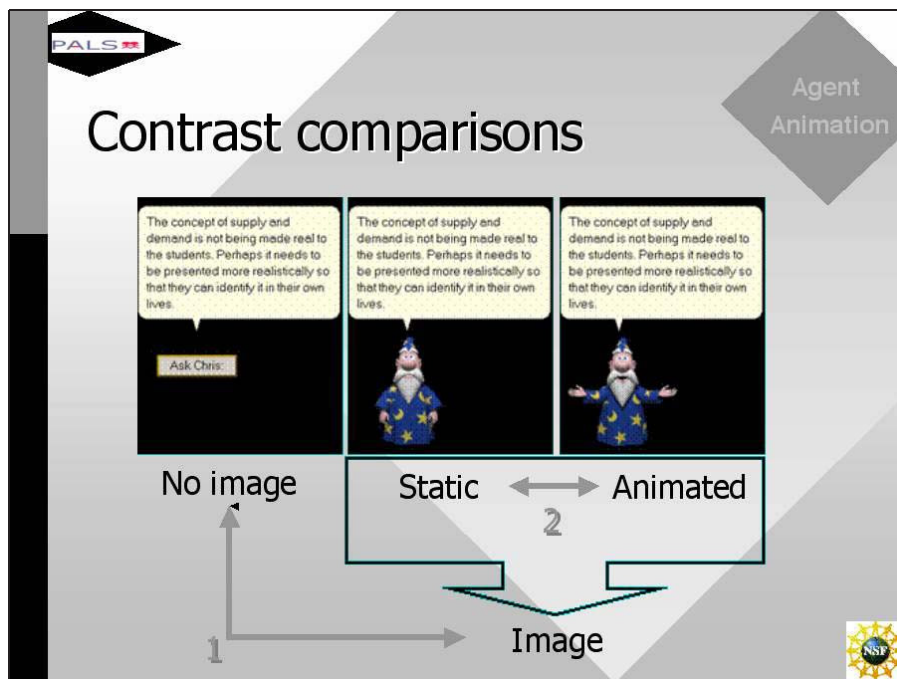
Figure 3

VOICE AND ANIMATION

Continuing with our preliminary work regarding agent animation, we also recently looked at the impact of animation presence/absence together with the effect of human versus computer-generated voice. We found that the presence of agent animation significantly facilitated improved learning from the agent, yet also negatively impacted learner motivation. The presence of a human voice, as predicted, led to the agent being perceived overall as more human-like (in terms of credibility, engaging, and instructor-like) but did not influence learning or motivation [13].
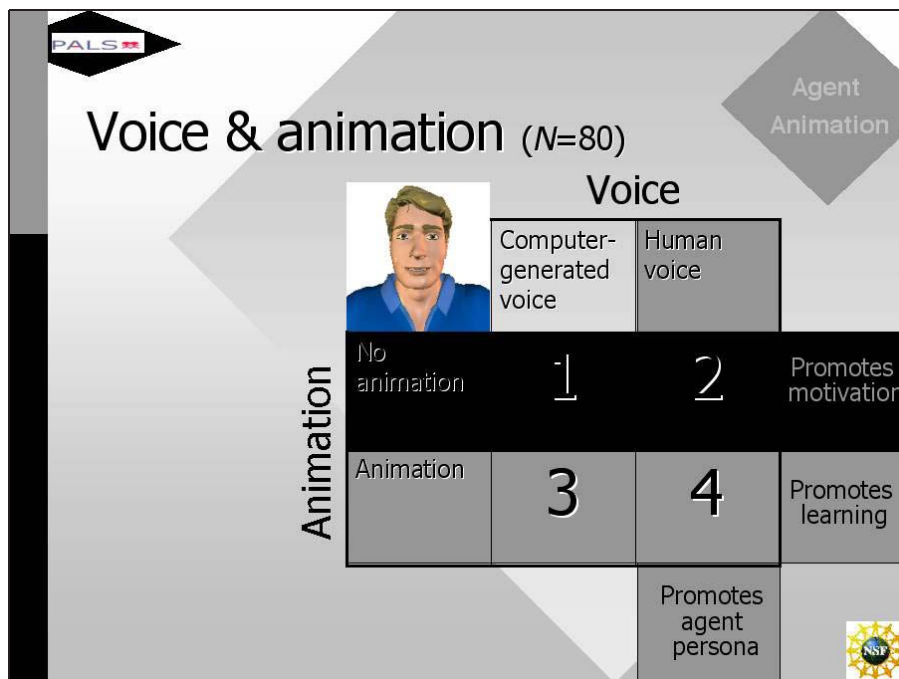
Figure 4

Our future work investigating agent animation will consider issues regarding the *nature* of the animation in terms of affect (e.g., emotional expression) and task-related aspects (e.g., gesture). Also, issues regarding cognitive load will be addressed in terms of how much the animations facilitate rather than distract from the learning task.

Figure 5

AGENT ROLES…

Our third area of focus is in the area of pedagogical agent roles, and we have looked at the roles of expert, motivator and mentor. Through validation studies, we first determined an effective operationalization of each of these roles in terms of image, animation, affect, script, and voice [9]. The Expert was designed to be expert-like in terms of presentation and content knowledge, whereas the Motivator lacked content knowledge, but supplied encouragement and ideas during the learning the process. The Mentor is essentially a combination of the Expert+Motivator in that he provided both motivation and expertise.

Figure 6

One of our most interesting results was found from controlled study of the Mentor agent alone versus the Expert + Motivator agents together (provided simultaneously) [10]. In both conditions, identical information and motivation was provided to the students since the Mentor was figuratively "split" into two separate agents as personified by the Expert and Motivator. We were surprised to find that students learned significantly more when the two agents were presented simultaneously (Expert and Motivator) than when the Mentor was just presented alone. We are terming this the "split persona effect."
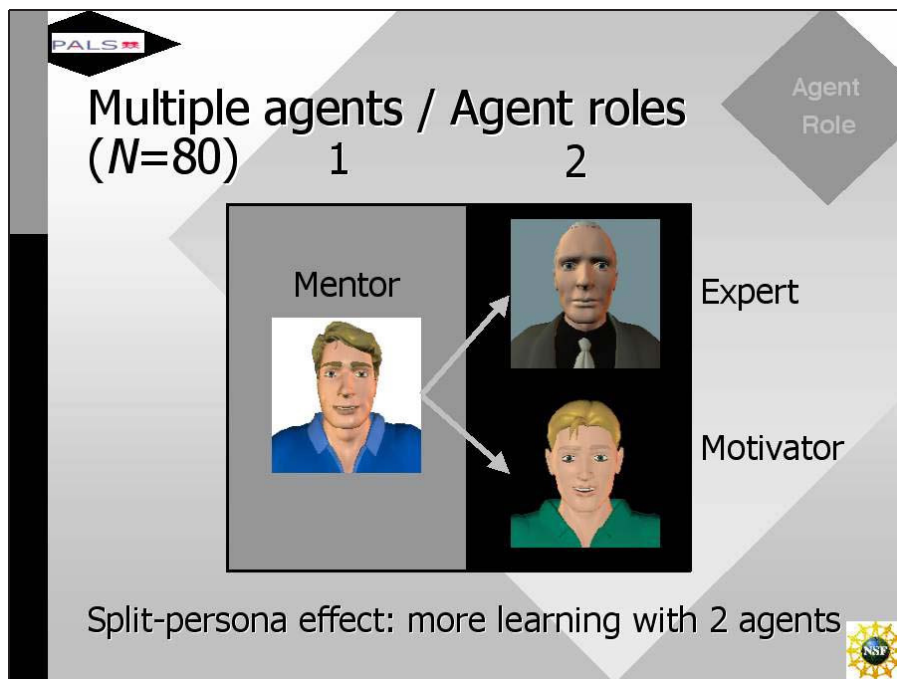
Figure 7

AGENTS AS REPRESENTING A ROLE OR PERSPECTIVE

Future work regarding agent role will investigate issues such as agents as peers or learning companions, and as mentors/role models for under-represented groups. We have collected a large amount of agent-learner interaction data and will be evaluating this qualitatively. The final area of immediate interest is the impact of multiple agents as a way to promote reflection and metacognition for the learner (e.g., see [5]).

Figure 8

RELATED WORK AND REFERENCES

For related work, see http://pals.fsu.edu and the references listed below.

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Language Use in Intelligent Tutoring Systems: Mixed Initiative Dialog in AutoTutor[1]

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INTELLIGENT TUTORING SYSTEMS

Over the last twenty years intelligent tutoring systems have proven to be very successful. From a theoretical academic perspective these systems have brought together disciplines like artificial intelligence, computer science, cognitive science, psychology and linguistics. But these systems have also been proven to be successful in a range of learning environments, including geometry, algebra, physics and electronics. In fact, the generations of systems have shown to provide learning gains, up to 1 standard deviation compared to students in a classroom (Corbett et al., 1999).

The latest generation of intelligent tutoring system uses conversational interfaces. These systems interact with student using natural language. Students can interact with the conversational system using written or spoken dialog and the system responds with language or speech. There are various reasons it is worth investigating these intelligent conversational tutoring systems. Of course, we are generally good at having conversations and this would benefit students. But more importantly, there are educational advantages. Interaction with a human tutor provides learning gains up to 2.3 standard deviations compared to classroom teachers (Corbett et al., 1999). A system that mimics the behavior of human tutors might therefore be desirable.

Intelligent Tutoring Systems

❑ Intelligent tutoring systems use intelligent computer-assisted instruction

❑ Produce significant learning gains beyond class room environments

❑ New generation of intelligent tutoring systems that hold mixed-initiative conversational dialogs with learner

    ❑ Atlas, Andes, and many others
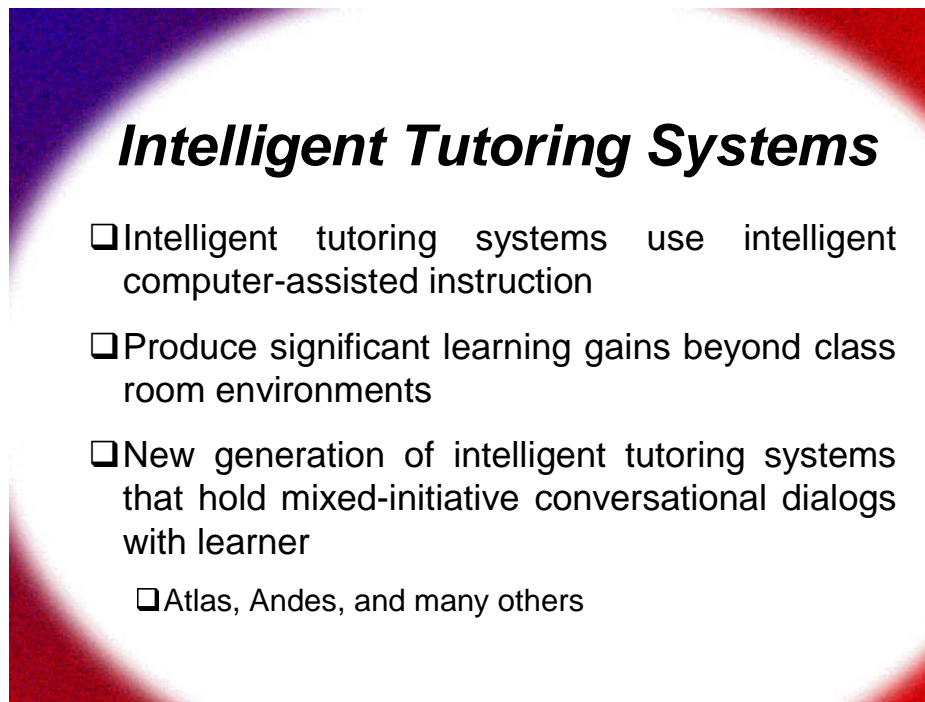
Figure 1

AUTOTUTOR

One such intelligent conversational tutoring system is AutoTutor. AutoTutor is a conversational agent that assists students in actively constructing knowledge by holding a conversation in natural language. AutoTutor has currently been developed for the domains of computer literacy and physics with the possibilities of development for a range of other domains. The system is web-based allowing to be used on any standard PC. Because AutoTutor is a client based application, the user only has to download a small number of files to be able to run the system, thus allowing for optimal use in educational environments (Graesser et al., 1999; 2001).

The system, its components and its effectiveness have been discussed in over 70 book chapters, journal articles and conference proceedings chapters (see http://www.autotutor.org). This presentation will summarize some of the main components of the system and focus on some of the natural language processing aspects of the system.
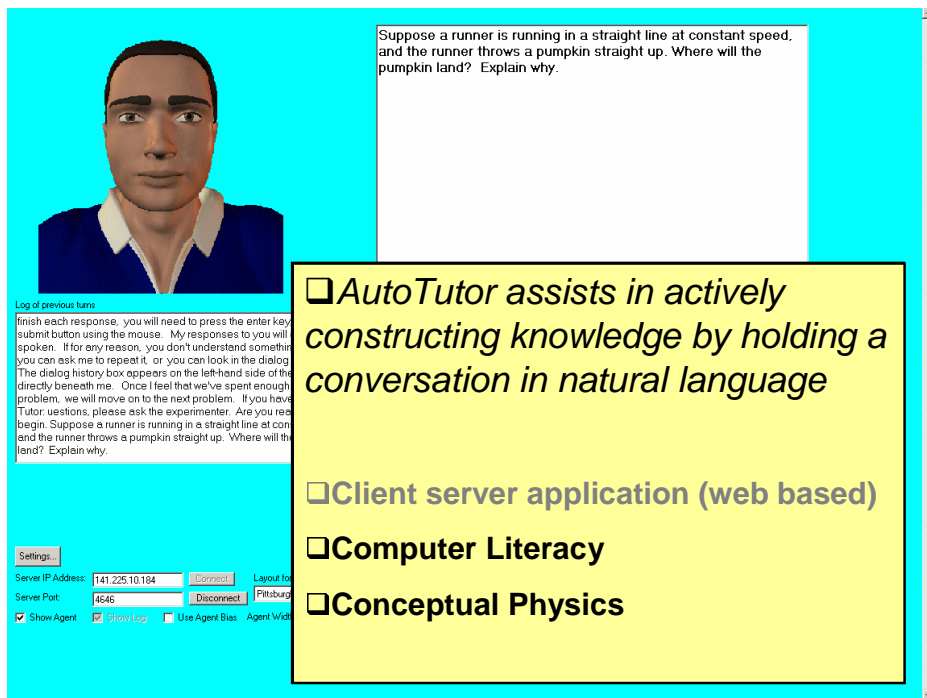
Figure 2

MOTIVATIONS BEHIND AUTOTUTOR

AutoTutor has been developed for computer assistant education. It helps students in their understanding of problems, concepts and terms in a particular domain. At the same time, AutoTutor helps teachers in providing their students with the tutoring of basic conceptual knowledge of a domain, leaving the real exciting challenges of tutoring for the human professional.

In addition, AutoTutor allows for testing of hypotheses. Understanding of how students behave in certain learning environments, how they react to certain dialog moves, whether they prefer a particular kind of tutor, all can easily be tested using intelligent tutoring systems. Although those experiments might miss the human aspect of tutoring, they allow for a maximum of controlling various variables.

Similarly, the development of AutoTutor has given rise to a range of research questions that might otherwise not have been raised. For instance, how important is world knowledge in tutoring? How easy is it to eliminate misconceptions? What makes language natural? When do language users consider dialog mixed-initiative?

Why AutoTutor?

❑ Computer assisted education

❑ Testing research hypotheses using a computer model is easier and more reliable than using a human tutor

❑ Research questions are generated by observing students' conversations with AutoTutor
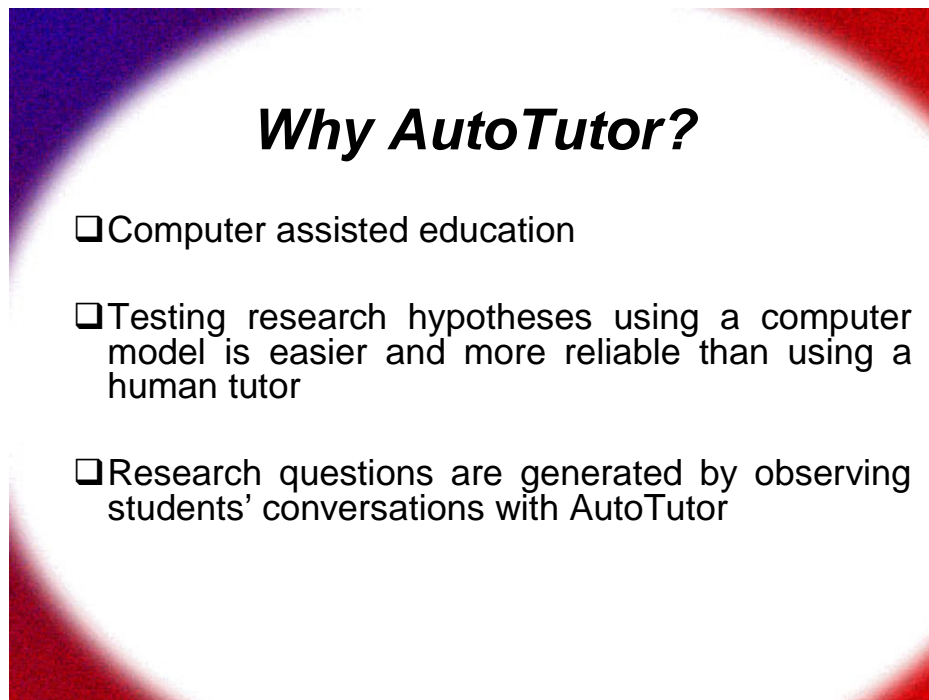
Figure 3

THE INTERFACE OF AUTOTUTOR

The interface of AutoTutor can be divided into four quadrants. The first quadrant consists of a talking head. AutoTutor uses synthesized speech to talk to the student, with facial expressions and rudimentary gestures to support this speech.

In the second quadrant a problem is presented to the student. In addition to presenting the problem or question, this quadrant can be used for visual information, including pictures, movie clips and interactive simulation.

The third quadrant is reserved for the dialog history with previous tutor and student turns are presented. This allows the student to look back on previous answers and tutor information. Although the dialog obviously allows for retrieving this information too (e.g. *could you repeat that?*), this history gives an overall log of the tutoring dialog.

The fourth quadrant is primarily used by the student. Although future versions of the system might use speech recognition, currently the student communicates with the system using written language. In the text box in the fourth quadrant the student can type answers to questions and problems presented by the tutor, various comments (e.g. *I don't understand*) and even various kinds questions (e.g. *what is the difference between velocity and speed?*).
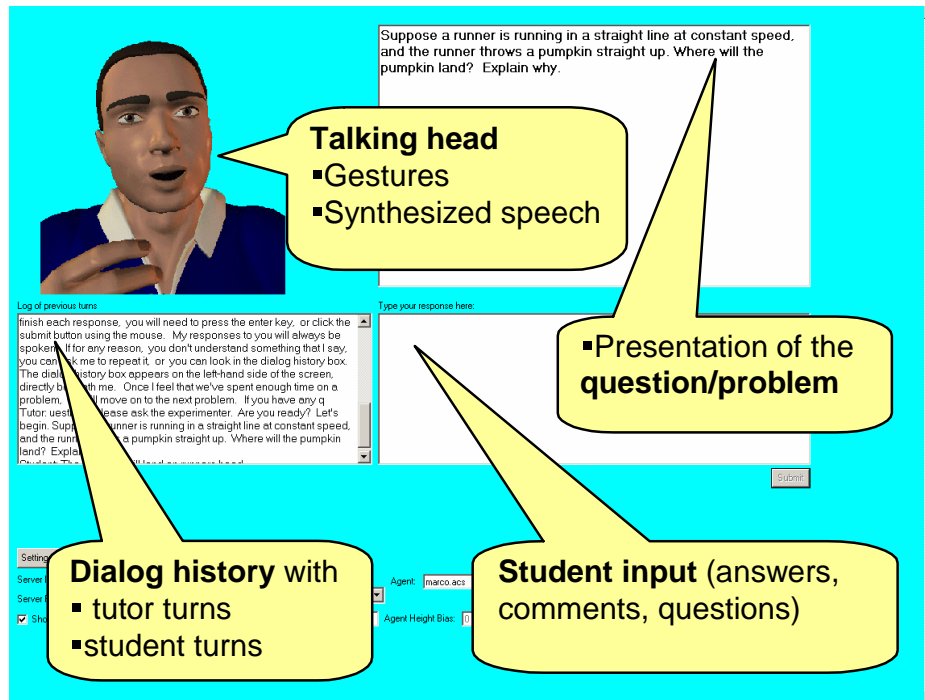
Figure 4

COMPONENTS IN AUTOTUTOR

At least four components can be distinguished in AutoTutor. First, the 'teacher' in AutoTutor organizes the pedagogical strategies (tutorial macrostructure). The 'thinker' in AutoTutor understands the meaning of the communication in general and the student's answers in particular (world knowledge). The 'dialog participant' in AutoTutor chooses the right dialog moves at the right time to keep the conversation organized (dialog advancer network). Related to this, the 'conversationalist' in AutoTutor uses a range of strategies to provide mixed initiative dialog. Each of these components is discussed next.
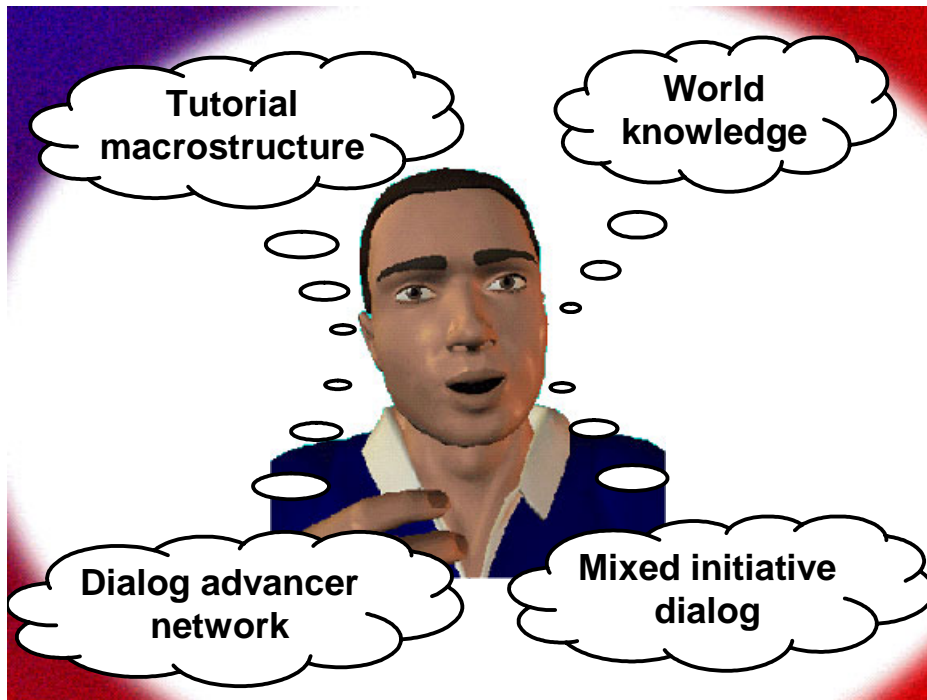
Figure 5

CURRICULUM SCRIPTS

Like most human tutors AutoTutor uses a macrostructural organization of the tutorial. For its didactic skills it uses curriculum scripts, loosely ordered sets of skills, concepts, example problems, and question-answer units. These scripts allow the tutor to keep track of the topic coverage and follow up on any problems the student might have. Although the tutor does not follow these curriculum scripts step-by-step, it does keep track of them as a guideline for the tutorial. The student thus has much flexibility in the conversation with the tutor, but the tutor is able to step in when the conversation seems to deviate too much from the structure of the tutorial (Graesser et al. 1999; 2001).

Curriculum Scripts

❑ loosely ordered sets of skills, concepts, example problems, and question-answer units

❑ keep track of the topic coverage and follow up on any problems the student might have
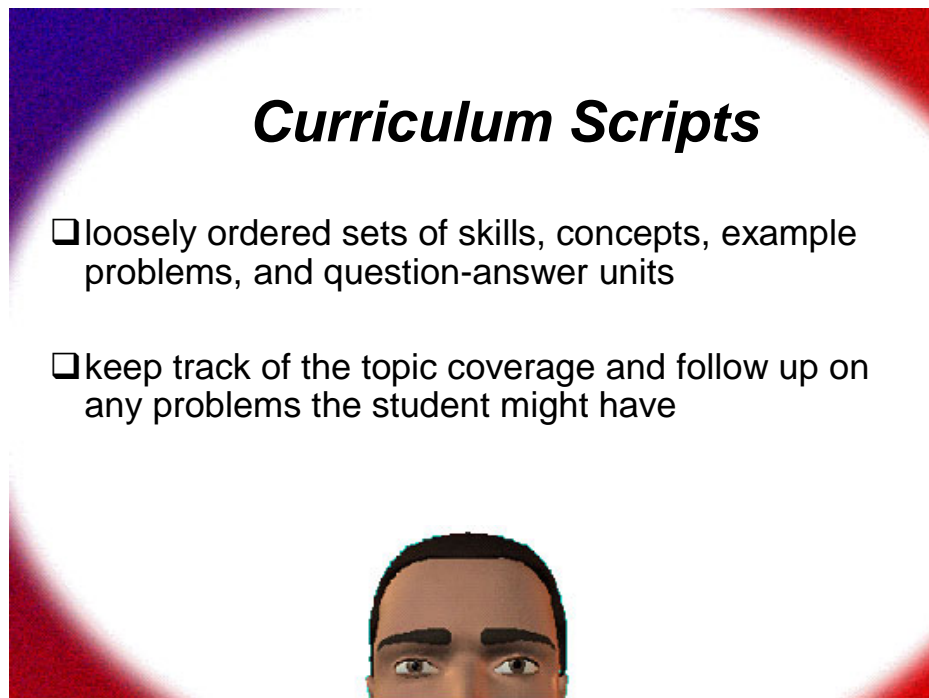
Figure 6

WORLD KNOWLEDGE

Understanding natural language requires world knowledge. AutoTutor uses Latent Semantic Analysis for its world knowledge. LSA uses singular value decomposition to reduce a co-occurrence matrix of words (or documents) to a cosine between two vectors.

The method of statistically representing knowledge has proven to be useful in a range of studies (see Franceschetti et al., 2001; Graesser et al., 2002). AutoTutor uses LSA as follows. The system presents a question related to a problem to the student and the student responds to this question. AutoTutor then analyzes the accuracy of this answer by comparing the student's answer with a series of expected ideal answers. This way the student covers a range of expectations in the tutoring sessions. The tutor allows the student to move to the next problem once all expectations are covered.
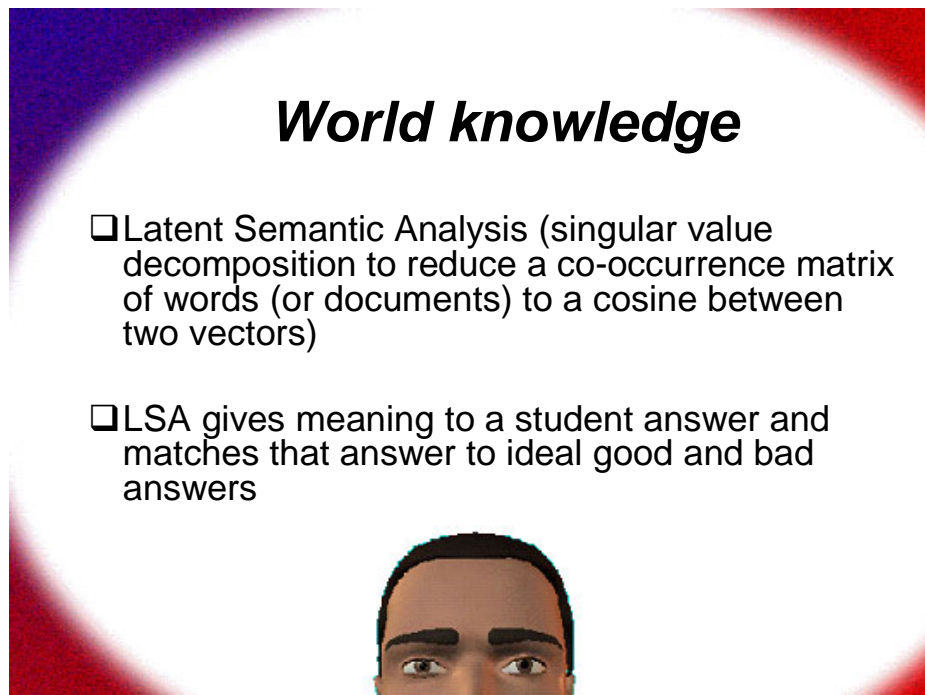
Figure 7

Mixed initiative dialog is the final component we earlier identified. Mixed-initiative interaction refers to the flexibility of strategies applied in the interaction between participants by those participants. It allows for the direction and control of the interaction to be shifted between participants. Mixed-initiative dialog requires that the participants engaged in the joint project (i.e. computer and human) act in coordination with each other (Allen, 1999).

Achieving mixed initiative dialog in computational environments is difficult. However, the question to be addressed in mixed-initiative interaction in intelligent systems is perhaps not whether models of human-computer interaction *are* mixed-initiative, but how the *impression* can be created that users are involved in mixed-initiative dialog. We have argued that the impression of mixed-initiative can be created by making the computer user believe that they are participating in a natural conversation (Louwerse et al., 2002). The more natural this conversation seems to be, the more likely the impression of mixed-initiative dialog is formed.

Mixed Initiative Dialog

➢ *A flexible interaction strategy, where each agent (human or computer) contributes what it is best suited at the most appropriate time*

(Hearst, 1999; Allen, 1999)

Figure 8

MIXED INITIATIVE DIALOG

At least four features of AutoTutor contribute to its conversational smoothness and its mixed initiative dialog. First, dialog moves direct the conversation. Second, discourse markers form the glue of the separate conversational units. Third, speech acts identify the speaker's intentions. Fourth, question answering gives the speaker the flexibility to ask questions and retrieve appropriate answers. Fifth, interactive simulation allows for manipulating variables in the real world (e.g. gravity) in order to understand various phenomena. Each of these features is discussed next.

Figure 9

DIALOG MANAGEMENT

AutoTutor's dialog management is designed to create a collaborative learning environment by determining the right tutoring strategy, to facilitate the student's active construction of knowledge and to facilitate conversational smoothness. Several of AutoTutor's dialog moves consist of a lengthy substantive contribution that prompts the learner for more information, that adds information, or that corrects a student error. These dialog moves don't particularly make AutoTutor a conversational and mixed-initiative system. More specific dialog moves that for instance prompt, hint and correct and thereby mimic natural tutoring sessions however are highly conversational (Person et al., 2001).

Dialog management

❑ Designed to create a collaborative learning environment by determining the right tutoring strategy

❑ Facilitate the student's active construction of knowledge

❑ Facilitate conversational smoothness by using synthesized speech, facial expressions and some rudimentary gestures
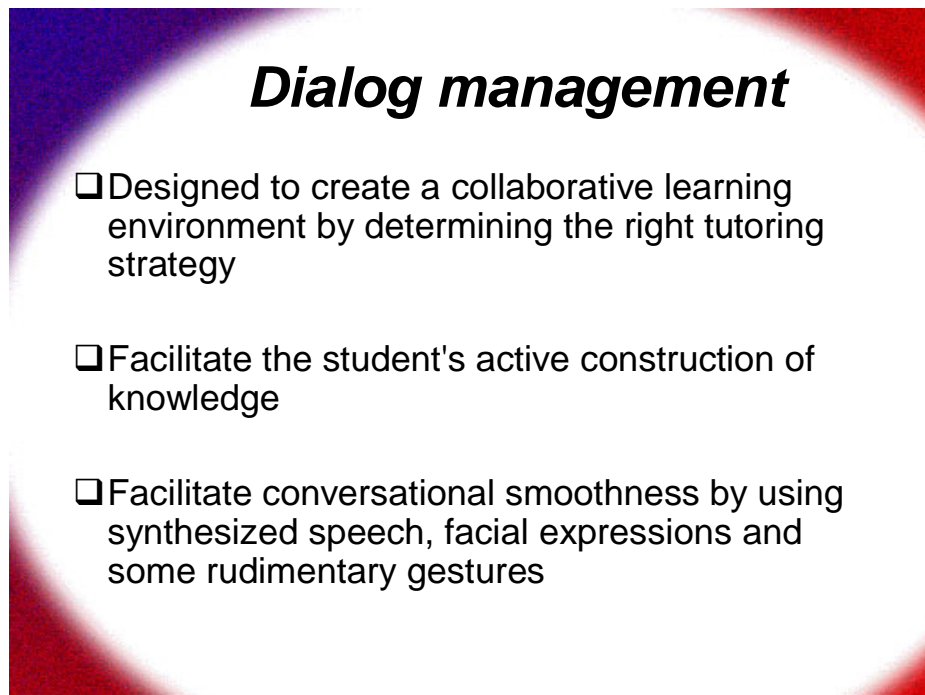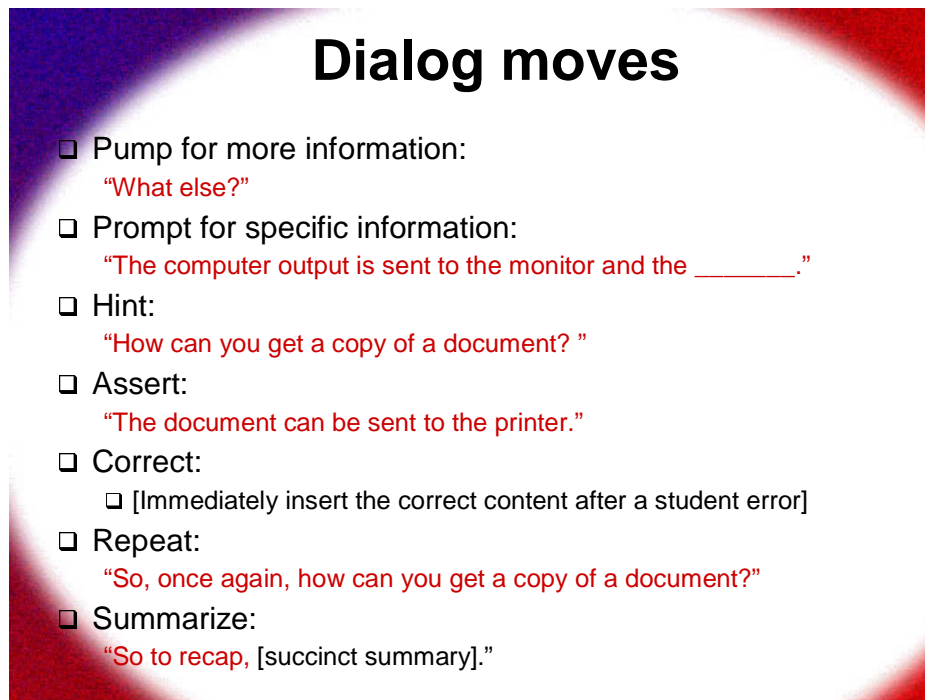
Figure 10

DIALOG MOVES

Seven kinds of dialog moves are used in AutoTutor's conversation: the system *prompts* for specific information; it *pumps* for more information; it *hints*, a*sserts, corrects, repeats* and s*ummarizes.* These dialog moves are organized by discourswe patterns in terms of their progressive specificity. For instance, hints are less specific than Prompts, and Prompts are less specific than Elaborations. AutoTutor therefore cycles through a Hint-Prompt-Elaboration pattern until the student articulates the correct answer (or rather reaches threshold *t* for covering all aspects of the ideal answer). The other dialog moves (e.g., short feedbacks and summaries) are controlled by fuzzy production rules (Graesser et al., 1999; Person et al., 2001). Examples from the version of the system developed for the domain of computer literacy of the different dialog moves are given below in Figure 11.
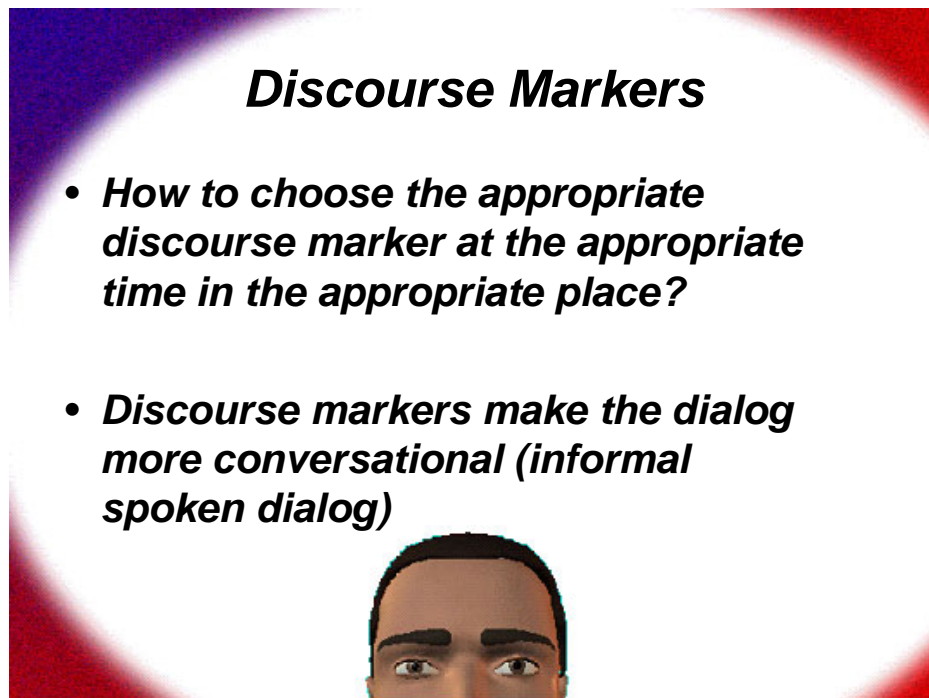
Figure 11

DISCOURSE MARKERS

Discourse markers are cues that facilitate the transition between turns in a dialog. They support the conversational smoothness. From various studies (see Louwerse & Mitchell, 2003) we know that discourse markers play an important role in informal conversational spoken dialog. They cue participants on previous dialog moves (e.g. *okay, right*), and mark relations with upcoming units of the dialog (*also, so*). Given that discourse markers play such a an important role, the main problem lies in choosing the right discourse marker at the right time in order to give the impression of conversational smoothness.

Figure 12

NETWORK OF DISCOURSE MARKERS

To select the appropriate discourse markers at the appropriate time and place, a taxonomy of these markers was generated from natural dialog. By sampling a large number of discourse markers from a natural corpus of dialogs and substituting each marker for all other markers, a network of semantic relations between these markers was generated (see Louwerse & Mitchell, 2003). The taxonomy that could be constructed out of these markers was implemented in AutoTutor. Random selections from large bags of discourse markers were made in order to give positive, neutral and negative feedback to the student, and to provide the student with a conversational continuity that can be found in natural dialog. The selections of markers are based on the dialog management in combinations with scores from latent semantic analysis (LSA). For instance, a high LSA score can lead to positive feedback (e.g. *Excellent! Well done!*), to neutral feedback (*Hmm, okay*) or to negative feedback (e.g. *No, not really*). Using the taxonomies of markers allowed for the impression of conversational smoothness in AutoTutor. By going beyond simple yes-no feedback the impression was created that the system was not fully in control of the conversation, but allowed for a conversation with the student.
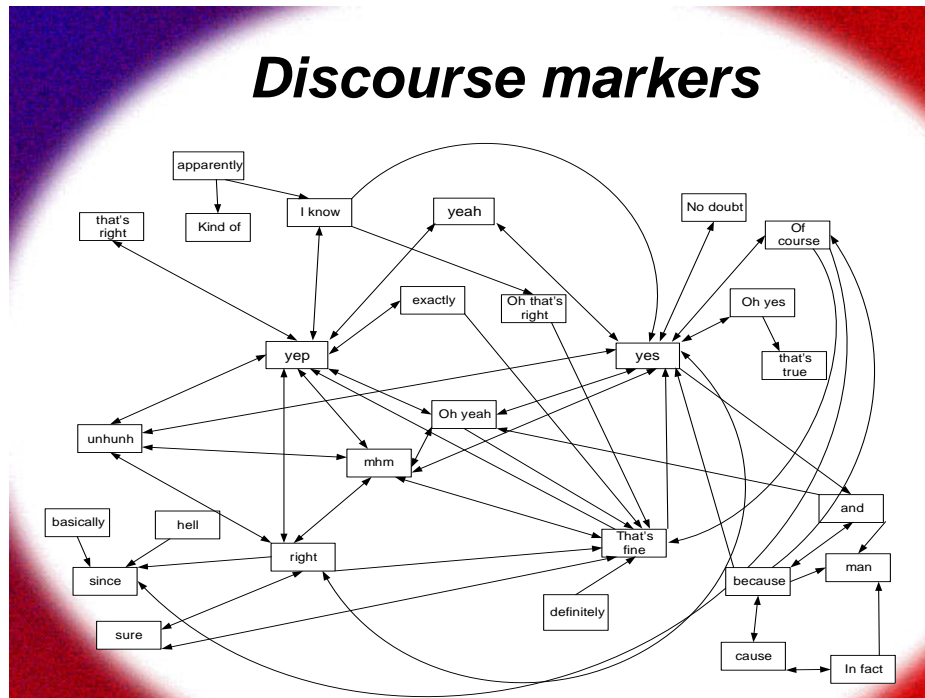
Figure 13

SPEECH ACT CLASSIFICATION

In natural conversation not only the meaning the meaning of a speaker's utterance is important, but also the intentions the speaker has expressing that utterance. AutoTutor classifies utterances into a range of speech acts. Although analyzing the pragmatics of dialog is difficult in terms of computational linguistics, we have developed a speech act classifier that identifies a large number of categories using surface linguistic features. In addition to assertions, the classifier identifies 20 illocutionary categories, ranging from directives (e.g. *hold on!*), metacommunicative expressions (e.g. *I didn't quite hear that*) and metacognitive expressions (*I don't know*) to 16 questions categories. These question categories consist for instance of definitional questions, verification questions, causal antecedent questions and example questions. With the classifier successfully been implemented in AutoTutor, the system now has ways to more appropriately respond to a student's input (Louwerse et al, 2002).

The speech act classifier is used to answer student's questions, is used to monitor a student's performance (e.g. does the student have many metacognitive problems?) and can be used to restructure the student's utterance to its intended meaning.

Figure 14

An example of the use of the speech act classifier is the restructuring of the original student's expression into an expression that better represents what the student tries to say. Take for instance the expression *I don't know what gravity is*. Strictly speaking this expression is an assertion, or more specifically a metacognitive statement. However, what the student really wants to know is the meaning of gravity. What looks like an assertion is in fact a question. AutoTutor's speech act classifier evaluates expressions and transforms them in an expression that better represents what the student intended
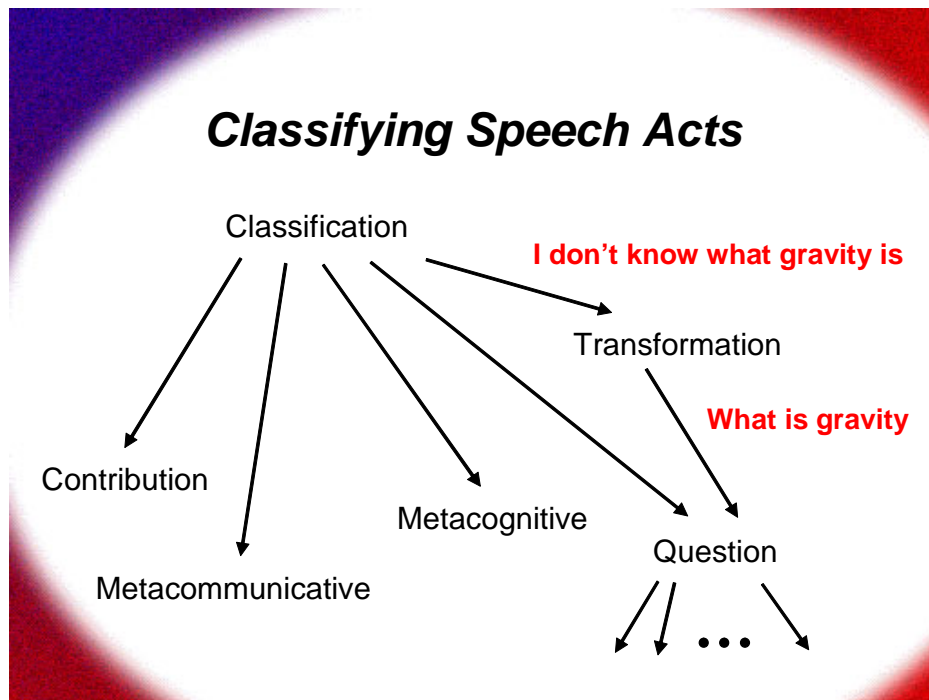
Figure 15

ANSWERING STUDENT QUESTIONS

As mentioned earlier, the speech act classifier categorizes a question into one of 16 categories, as identified by Graesser & Person (1994). This taxonomy distinguishes itself from other proposals in at least two respects. First, the question categories are defined according to the content of the information sought rather than on question signal words (*who, what, why, how*, etc.). That is, a speaker asking *How can you define gravity?* requests a different answer than a speaker asking *How does gravity affect the earth's orbit around the sun?* despite the fact that the signal word (*how*) is the same for both questions. Secondly, the taxonomy makes a distinction between the type of questions asked from a learner's perspective. One the one hand it identifies shallow comprehension questions that do not require a deep insight into a topic (questions 1-8 in Figure 16), on the other deep comprehension questions that require inferences in addition to dictionary or encyclopedic knowledge (questions 9-16 in Figure 16). Not surprisingly, deep comprehension questions and their answers will likely lead to higher learning gains. By identifying these 16 categories and the two types of questions in particular, AutoTutor can monitor a student's educational challenges.

Types of questions
(Graesser & Person, 1994)

Question Category	Example
Verification	Is the answer 5?
Disjunctive	Is gender or female the variable?
Concept Completion	Who ran this experiment?
Feature Specification	What are the properties of a bar graph?
Quantification	How many degrees of freedom are on this variable?
Definition	What is a t test?
Example	What is an example of a factorial design?
Comparison	What is the difference between a t test and an F test?
Interpretation	What is happening in this graph?
Causal Antecedent	How did this experiment fail?
Causal Consequence	What happens when this level decreases?
Goal Orientation	Why did you put decision latency on the y-axis?
Procedural	How do you present the stimulus on each trial?
Enablement	What device allows you to measure stress?
Expectational	Why isn't there an interaction?
Judgemental	What do you think of this operational definition?

Figure 16

QUESTION ANSWERING SYSTEM: QUEST

Identifying student questions without being able to answer these questions would be awkward. Using the speech act classifier AutoTutor is able to answer student questions by providing the information they seek. This question answering system (QUEST) thus allows for student initiative. Without knowledge engineering, the system uses question classification and latent semantic analysis to retrieve a paragraph from a text book that best fits the answer the student is looking for (Louwerse et al., 2002).
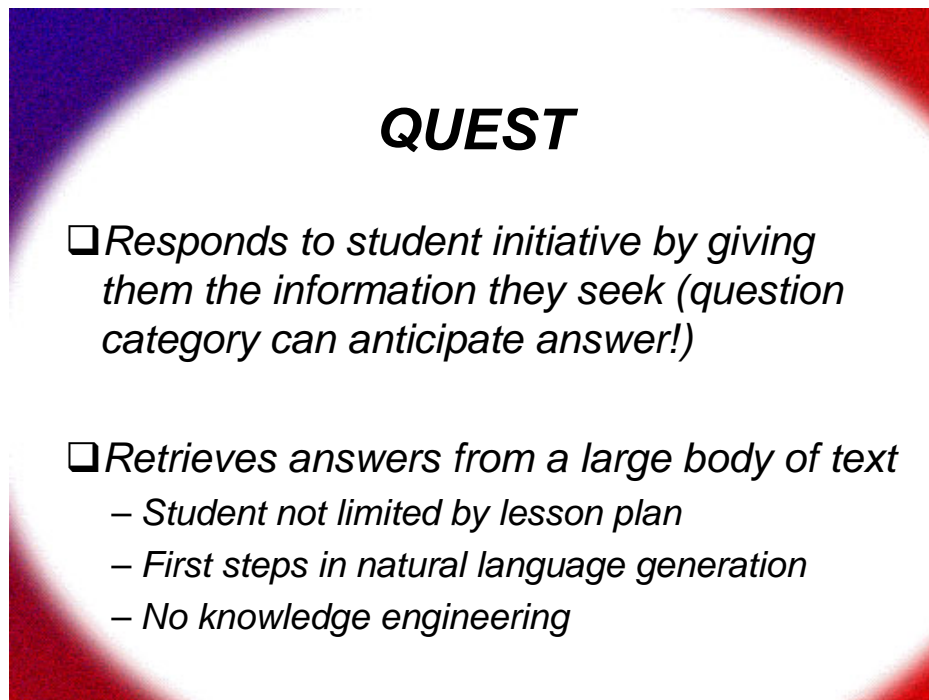
Figure 17

STRENGTHS OF QUEST

QUEST offers some important advantages. First, of course, it allows for mixed initiative dialog. The student does not only listen and answer, but can challenge the system with questions as well. Because QUESTS uses answers that are based on the information in a textbook, the student gets the answers in needs. Another important advantage is that QUEST performs best on those questions that are considered deep comprehension questions in the Graesser & Person, 1994) classification. For learning environments this is an important advantage, given that this is the type of questions good students are expected to ask. Finally, the speech act classification and latent semantic analyses mechanisms allow the answer to be easily embedded in the conversational framework. With a minimum of efforts the knowledge domain of QUEST can be changed and computational linguistic modules are used that are already present in the conversational framework of AutoTutor.

Strengths of QUEST

❑ *Gives detailed answers based on what the student learns from the text book*

❑ *Questions considered difficult to automatically answer (e.g. causal antecedent, comparison questions) have highest performance scores*

❑ *The answers can easily be embedded in a conversational framework*
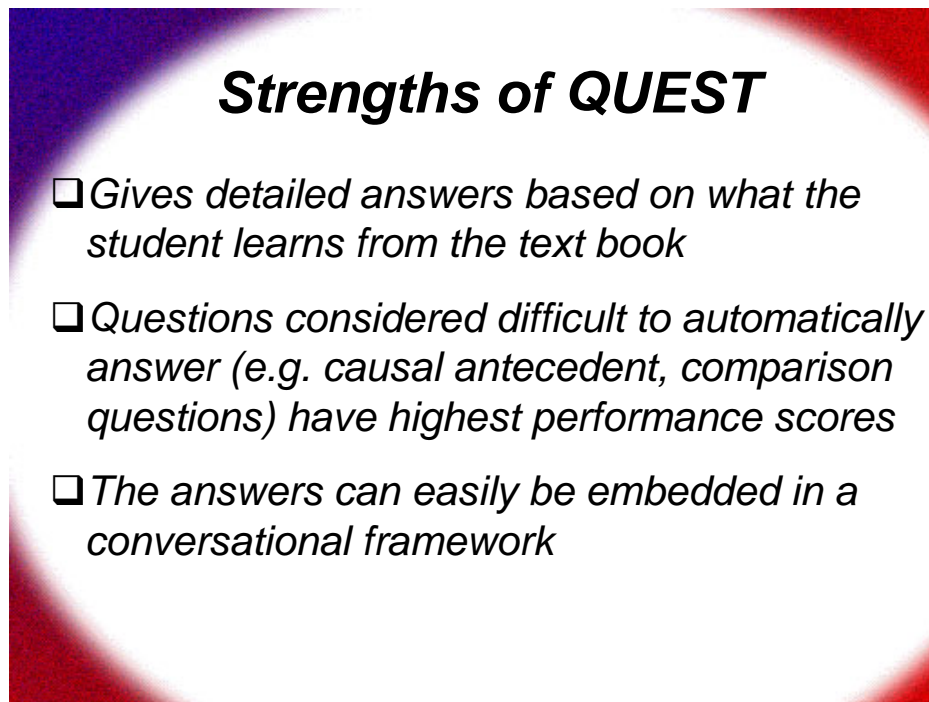
Figure 18

INTERACTIVE SIMULATION

The final aspect of mixed initiative dialog goes beyond natural language processing only. AutoTutor uses interactive simulation environments can change parameters and control the simulation. All simulations were designed to be web deliverable and to simulate specific conceptual physics problems. However, instead of interactive simulations only, content specific dialogs accompany the simulations in order to motivate the learner to explore the simulation environment, followed by a discussion with the avatar pertaining to the concepts. During the simulation the system guides the student, while the student can take control of the simulation and dialog at any point (see Haynes et al., under review).
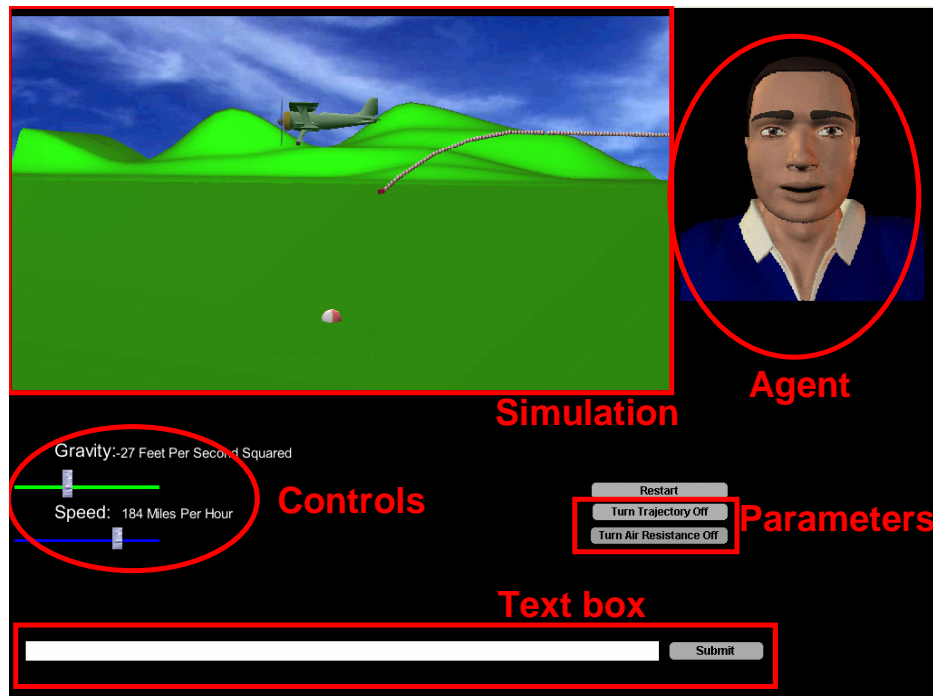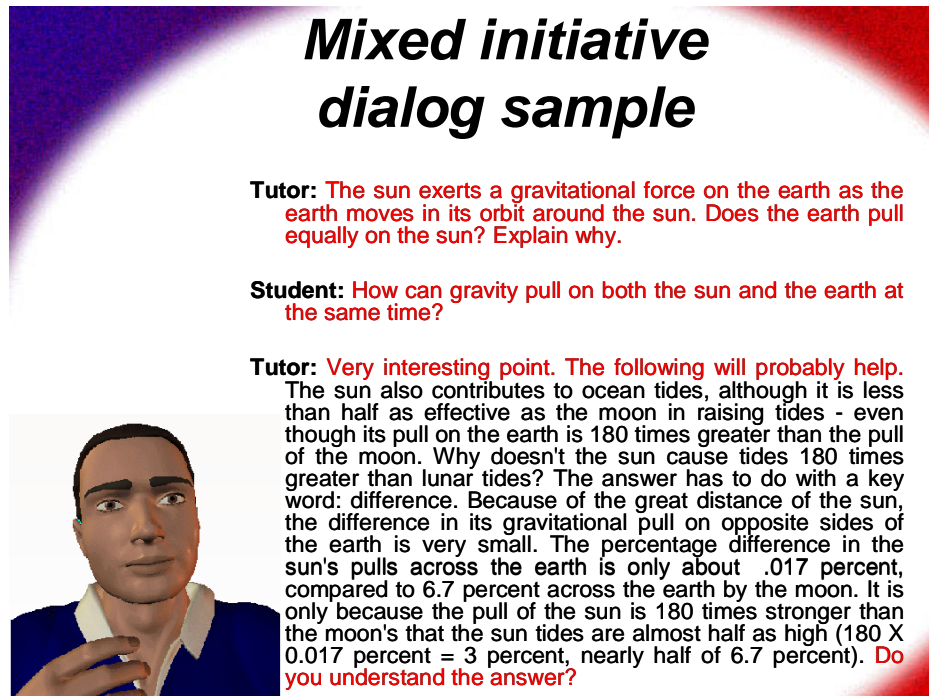
Figure 19

EXAMPLE OF AUTOTUTOR DIALOG

We have discussed the various aspects of mixed initiative dialog in AutoTutor. To give an impression of a typical dialog, Figure 20 and 21 give examples taken from AutoTutor log files. Figure 20 shows the tutor first presenting a problem. Instead of the student answering the tutor's question, she asks another question, which the system answers introducing the answer and asking whether the answer is sufficient.

Mixed initiative dialog sample

Tutor: The sun exerts a gravitational force on the earth as the earth moves in its orbit around the sun. Does the earth pull equally on the sun? Explain why.
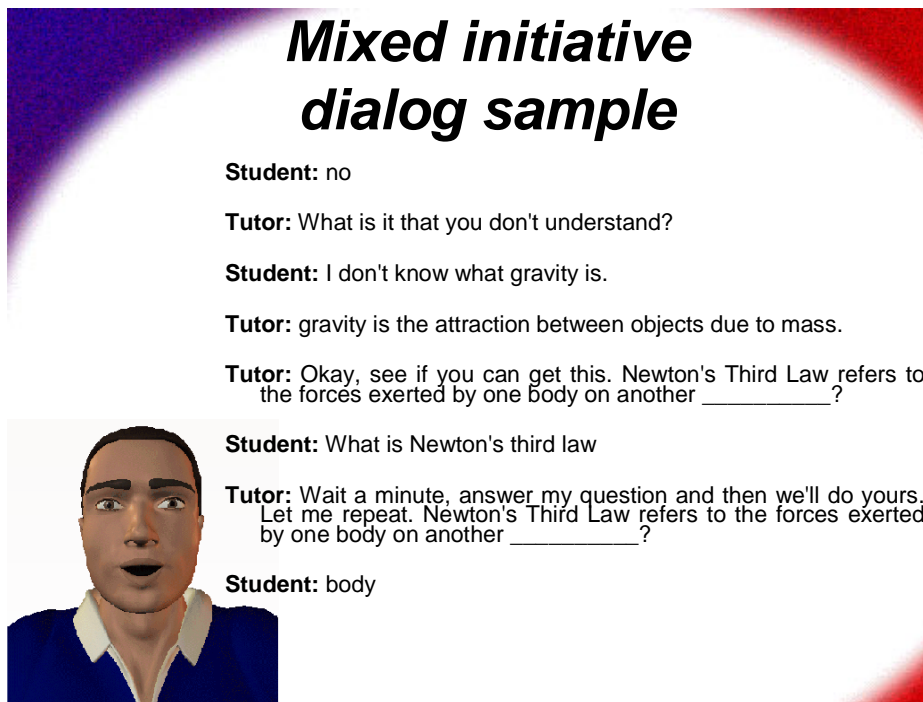
Student: How can gravity pull on both the sun and the earth at the same time?

Tutor: Very interesting point. The following will probably help. The sun also contributes to ocean tides, although it is less than half as effective as the moon in raising tides - even though its pull on the earth is 180 times greater than the pull of the moon. Why doesn't the sun cause tides 180 times greater than lunar tides? The answer has to do with a key word: difference. Because of the great distance of the sun, the difference in its gravitational pull on opposite sides of the earth is very small. The percentage difference in the sun's pulls across the earth is only about .017 percent, compared to 6.7 percent across the earth by the moon. It is only because the pull of the sun is 180 times stronger than the moon's that the sun tides are almost half as high (180 X 0.017 percent = 3 percent, nearly half of 6.7 percent). Do you understand the answer?

Figure 20

The student responds negatively to the question whether the answer is sufficient and the tutor follows up asking what was unclear in its answer. When the student points out the confusion, the system then follows up with another answer to the question. However, when the system has answered and starts with the next tutoring question and the student asks yet another question, the teacher in AutoTutor steps in. Instead of allowing for total flexibility in the conversation, AutoTutor now takes back the control of the dialog.

Mixed initiative dialog sample

Student: no

Tutor: What is it that you don't understand?

Student: I don't know what gravity is.

Tutor: gravity is the attraction between objects due to mass.

Tutor: Okay, see if you can get this. Newton's Third Law refers to the forces exerted by one body on another _____?

Student: What is Newton's third law

Tutor: Wait a minute, answer my question and then we'll do yours. Let me repeat. Newton's Third Law refers to the forces exerted by one body on another _____?

Student: body
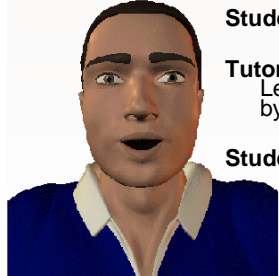
Figure 21

OVERALL STRENGTHS OF AUTOTUTOR

AutoTutor has various strengths (see Graesser, 1999; 2001; Louwerse et al. 2002; Person et al., 1999). It is an existing system that requires a minimum of computer specifications. Furthermore, AutoTutor is not domain specific. Because of the various natural language processing modules discussed in this presentation, AutoTutor requires only a minimum of adjustments for a new domain (approximately three months for a basic version of the system). More specifically, only the knowledge domain and the curriculum scripts need to be changed for the new domain. Authoring tools have been developed to facilitate this process. Furthermore, the system adapts to student. Studies have shown that AutoTutor uses different pedagogical strategies and different frequencies of dialog moves for high ability versus low ability students, thus allowing for a certain extent of user modeling. Finally, AutoTutor is conversational, so much that experiments have shown that subjects cannot distinguish between dialogs controlled by AutoTutor and dialogs controlled by human tutors. However, the system does not just control the dialog. It takes control whenever this is necessary, but allows the student to contribute what is best suited at the most appropriate time, providing mixed initiative dialog.
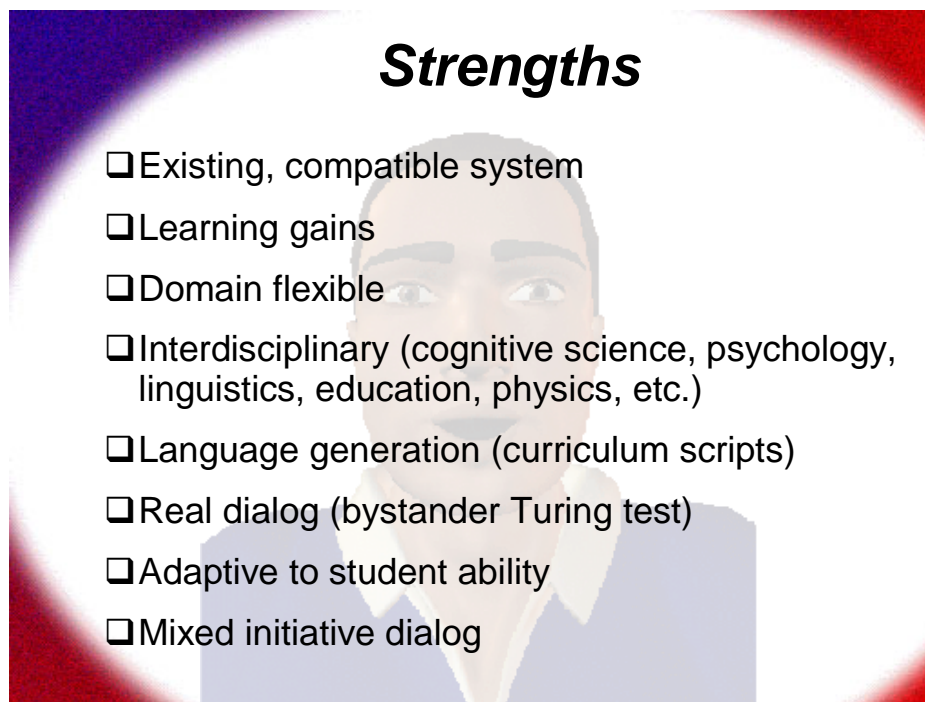
Figure 22

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Coming To Terms with Social Constructivism

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COMING TO TERMS WITH SOCIAL CONSTRUCTIVISM

Throughout this workshop, social constructivism - the idea that people construct what they learn through social interaction with other people (Palincsar, 1998; Wilson, 1996) - has been lurking in the background of our discussions.

I want to talk today about how I have begun to come to terms with the ideas of social constructivism in my own work. It has been a process, one that is still underway.
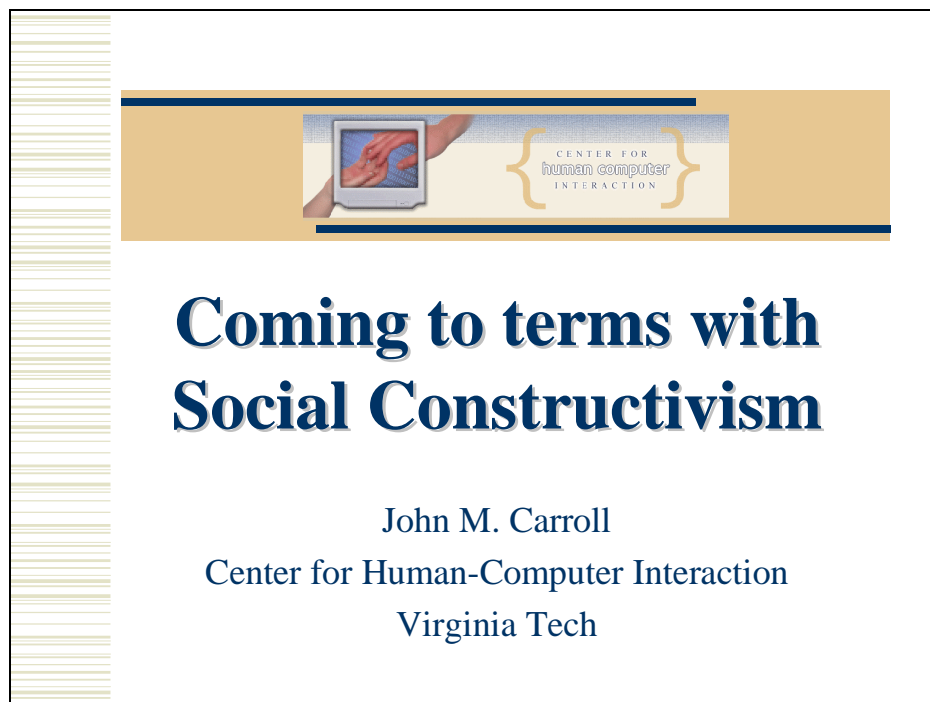
Figure 1

OUTLINE OF TALK

I started out life as a cognitive psychologist, and was taught to regard "learning" as a matter of information processing mechanisms. However, I worked for the first 18 years of my career in industry (at IBM's Watson Center) and for the next 10 as a university professor (at Virginia Tech). In both cases, I was repeatedly impressed that learning is more than a matter of sequences of learning events and practice.

Learning occurs when people carry out authentic tasks, in realistic contexts - including committing, diagnosing, and recovering from errors, when they are able to explore and discover on their own initiative, reflect upon and draw lessons from their activity, when they are able to work with others, socially model the practices of others, and share meaning with others. I have detailed my own itinerary as a researcher on learning in a series of books - Carroll, 1990, 1998, 2000.

Figure 2

RESEARCH THEMES

Social constructivist ideas about learning have direct implications for designing teaching practices and technology. First, designers should collaborate directly and deeply with domain experts. This means more than just knowledge engineering for the given domain. It means understanding teaching and learning in the domain.

Second, designers need to provide learners with open-ended tasks. People cannot be expected to make meaning out a dreary, over-programmed practice. Significant learning activities always incorporate discovery.

Third, designers must incorporate collaborative learning into new teaching practices and technologies. Whether "agents" can be effective surrogates in collaboration, and whether purely asynchronous interaction with others is sufficiently stimulating are current technical questions.
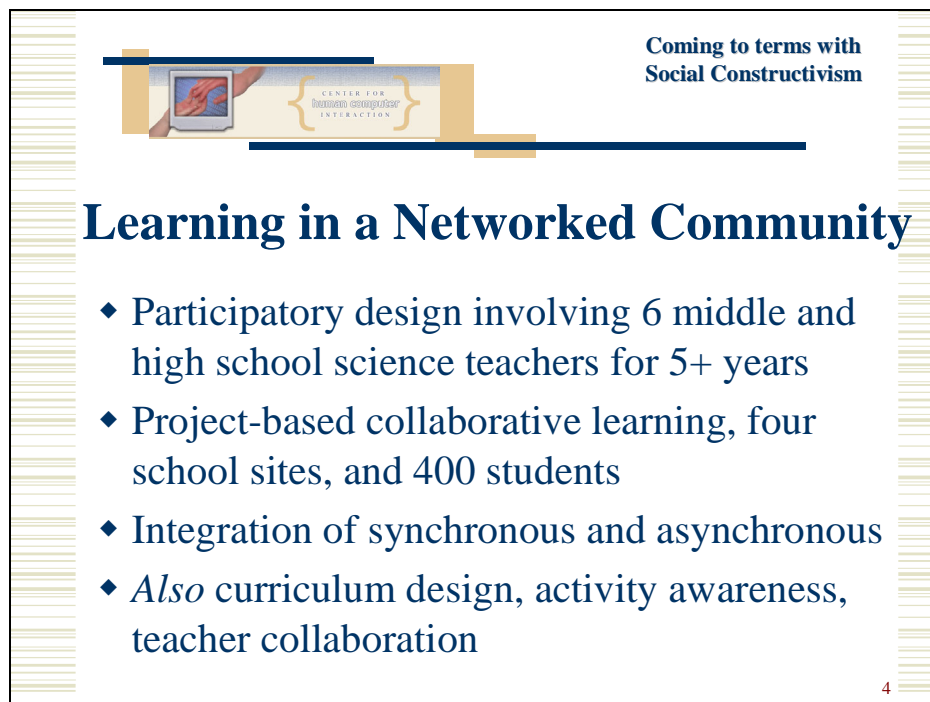
Figure 3

LEARNING IN A NETWORKED COMMUNITY (LiNC)

In 1995, my group began a long-term collaboration with public school divisions in southwestern Virginia to explore the feasibility of employing Internet collaboration in high school and middle school science, as part of NSF's "Networking Infrastructure for Education" initiative. A specific problem faced in these rural areas is that often there is insufficient critical mass for science courses, which of course adds to the inequity already faced by students from these areas. The technologies and approach we developed are of course more general than this, and in fact are widely applied in so-called distance education.

We worked with 6 teachers for more than 5 years. Our program eventually involved more than 400 students. Our initial technical objective was to integrate synchronous and asynchronous collaboration. It was obvious even then that this would be a major challenge for getting distance learning visions to work. But along the way, we encountered a large set of other issues, some of which are far more challenging.

Figure 4

THE VIRTUAL SCHOOL

This is the first version of our Virtual School system. It clearly makes the point of how important awareness and coordination are in collaborative work. In center of the screen, is the shared notebook; the sharing is at the level of sections. Collaborators can embed annotations in the shared document. The green lock indicates that we are working on the Robot Pictures section; the red lock indicates that others are working on the Introduction

A video window helps keep us aware of remote collaborators. Chat and Email (not shown here) are also used to coordinate. A Notice Board tool (in the lower left) displays recent project chronology, an inventory of shared objects (in this case, just the robotics notebook), and a roster of group members - indicating who is available/unavailable. (See Isenhour et al., 2000.)
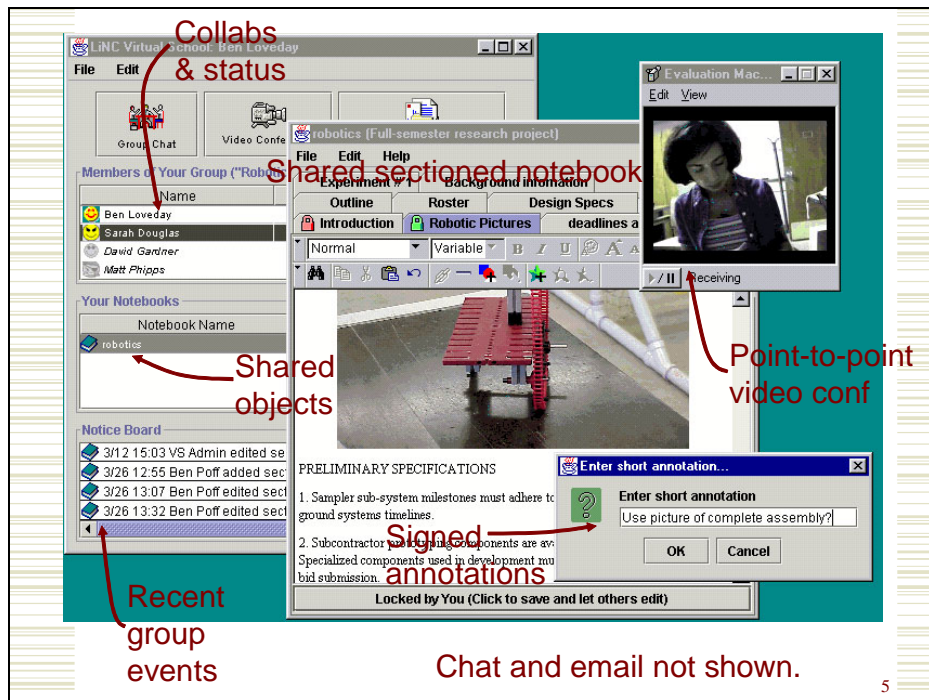
Figure 5

EARLY OUTCOMES

Our in the objective in the LiNC project was to explore a new paradigm for collaborative, project-based science. This involves both collaboration outcomes and learning outcomes. On both fronts, we had encouraging but inconclusive results. We were able to over-come many remote collaboration problems. We were able to analyze the challenge of activity awareness and a variety of technical approaches to managing it (Carroll, Neale, et al., 2003).

With respect to learning outcomes, we relied primarily on our partners in the public school systems. They concluded that this intervention was successful in promoting the educational goals by which they are measured. Two of the 6 teachers that worked with us continued using our software in their classroom even after our NSF funding expired. We have continued to work with these school systems in a series of further projects.

Figure 6

One of our most important outcomes in the LiNC project was something we were not looking for. To make collaborative learning work, teachers have to work together too. The challenges of technology with respect to the culture of teaching and the school is well-known. But analogous issues exist with respect to collaboration (Tyack & Cuban, 1995).

In the LiNC project, teachers collaboration, and responsibility-taking more generally, increased as we went along. We were able to identify developmental patterns and trajectories in the roles that the teachers we worked with played in our joint project. A key mechanism, we believe, is serious and long-term commitment to participatory design, an approach in which "users" and "developers" of technology share equal power and responsibility. (See Carroll et al., 2000.)
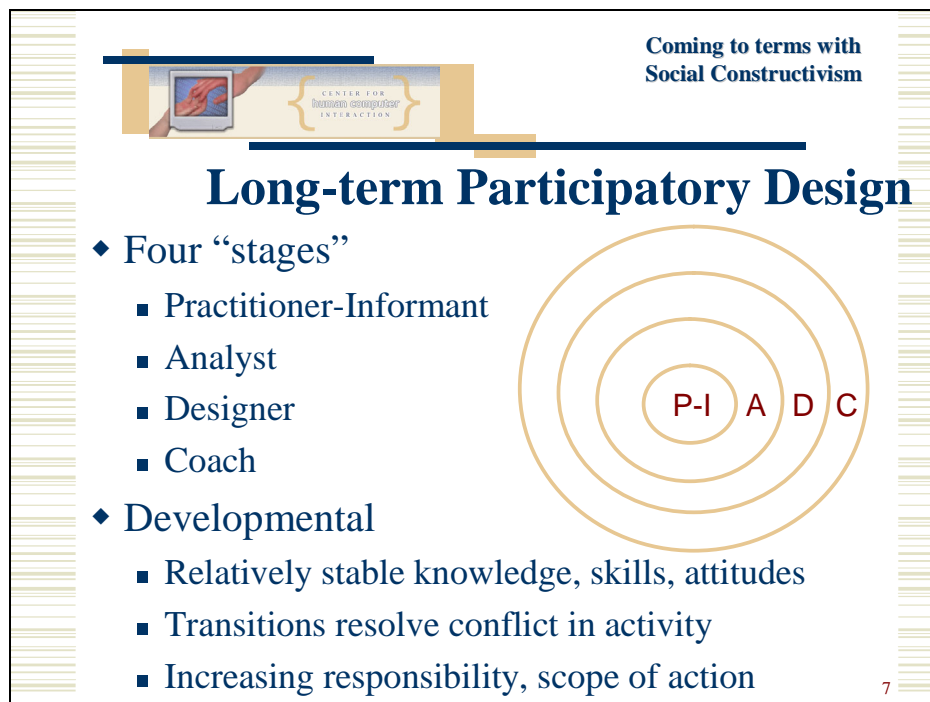
Figure 7

CURRENT TECHNICAL DIRECTIONS

Our work is continuing along four directions. First, we have tried to enhance the software infrastructures that enable systems like the Virtual School. To support seamless collaboration and learning, teachers and students need to be able to configure such systems.

Second, we are continuing to investigate activity awareness; we see this as a major issue in enabling collaborative work systems.

Third, we have shifted some of our focus from students to teachers. Supporting continuous teacher professional development is both a prerequisite for the sort of educational vision we are pursuing, and a possibility afforded by this vision.

Fourth, we are developing and investigating new collaborative learning activities; as has always been true, new technologies both enable and require new approaches in human activity.
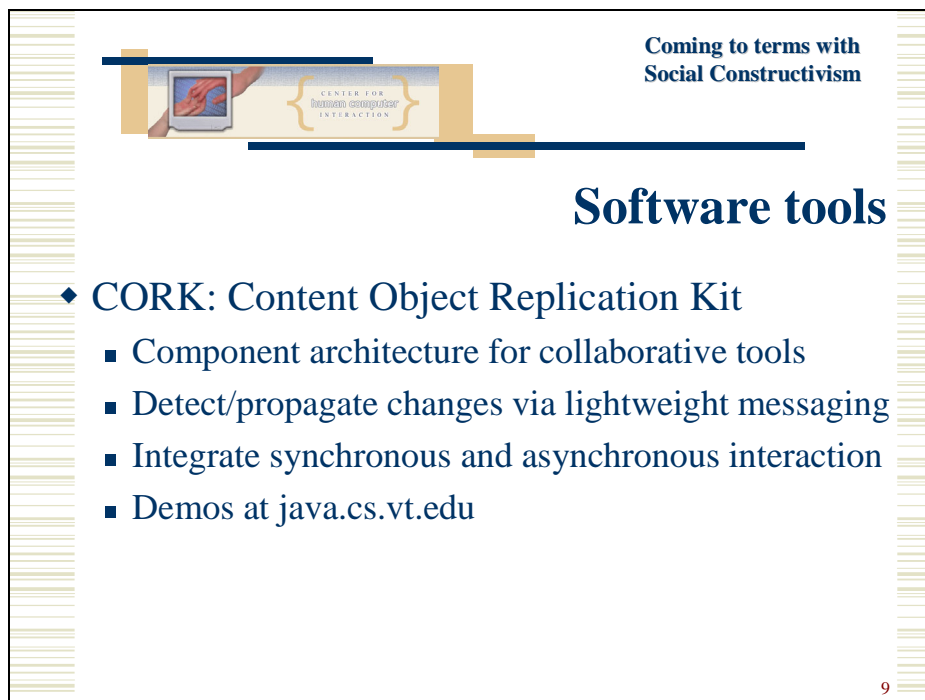
Figure 8

SOFTWARE TOOLS

Today, the World-Wide Web is the default infra-structure for educational collaborations. However, the Web is a publishing infrastructure. With support from ONR, we developed the Content Object Replication Kit (CORK) to enable lightweight collaborative interaction.

In the object replication approach, changes in a local object are broadcast to subscribed collaborators and to a central server in order to update all replicas. On the one hand, this approach requires less network bandwidth than broadcasting the objects themselves, and, on the other hand, it enables asynchronous collaboration, not possible with screen sharing approaches.

Figure 9

CORK EXAMPLE

Here is an example. The client at the left updates the map, and a change object is broadcast both to the collaborating client, at the right, and to the central server, depicted at the bottom right. Activity in the collaborating client is very minimally affected at all; the clients are synchronized on a 'when possible' basis. We described this in more detail in Isenhour et al. (2001).
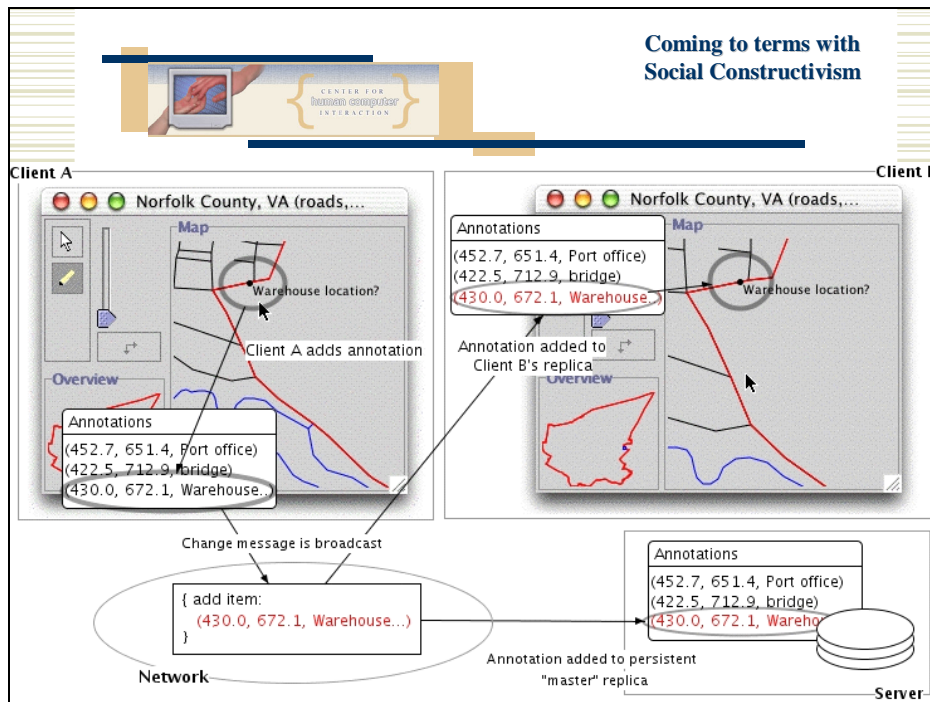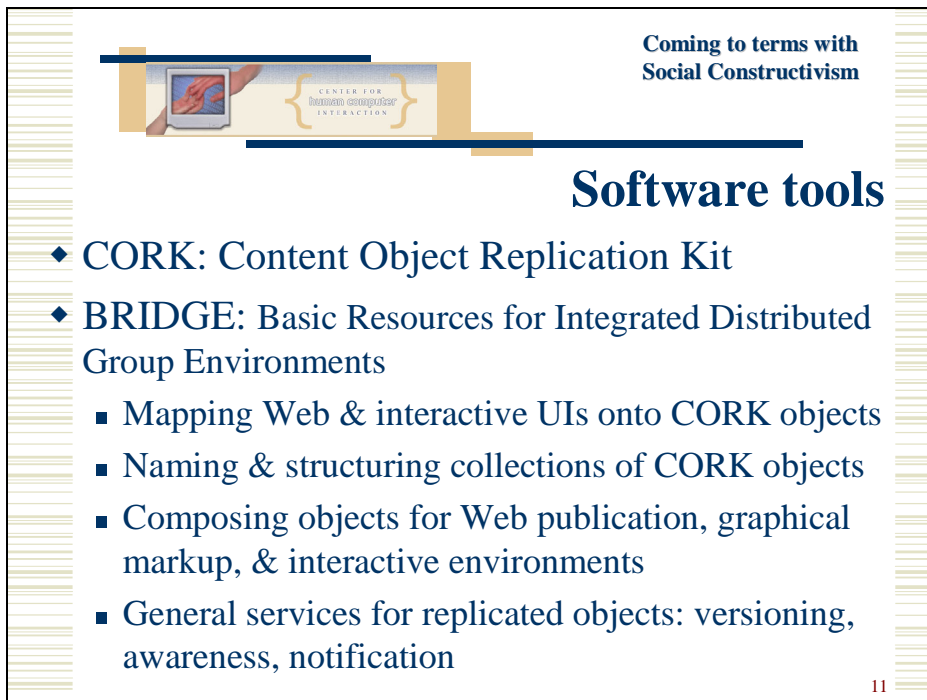
Figure 10

BRIDGE

More recently, we have developed a tool layer to provide file system and user interface services for CORK objects. This layer, called BRIDGE - Basic Resources for Integrated Distributed Group Environments - is intended to make it easier for people to collaborate directly via the Web.

Figure 11

EXAMPLES OF BRIDGE

These are examples. Bridge provides a file system view of CORK objects. It provides awareness information, such as the currently-subscribed users of an object. And it provides standard ways of rendering CORK objects, such as maps and tables.
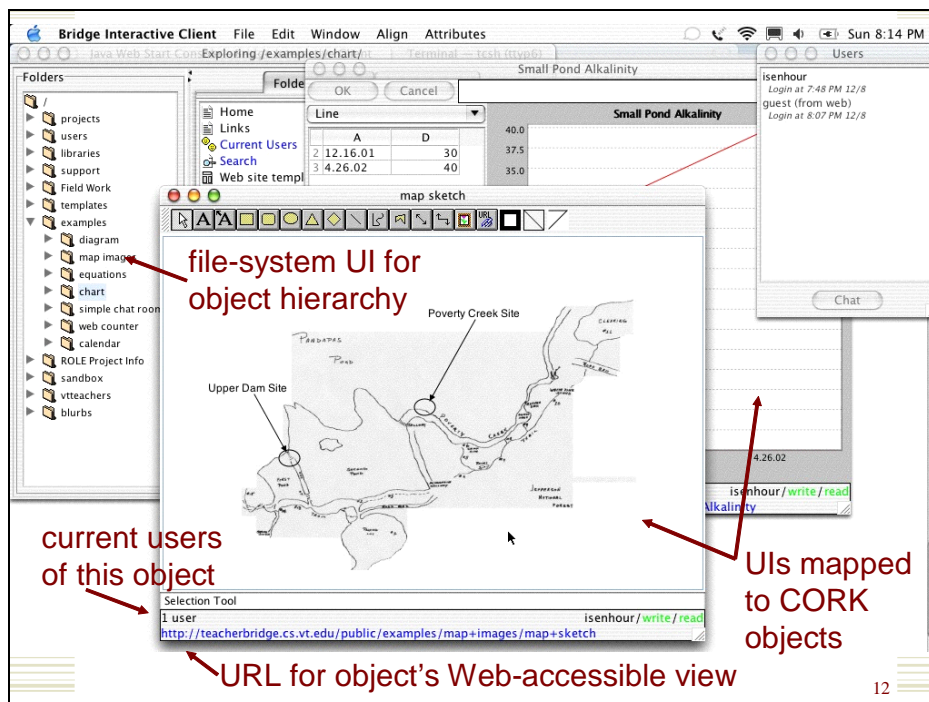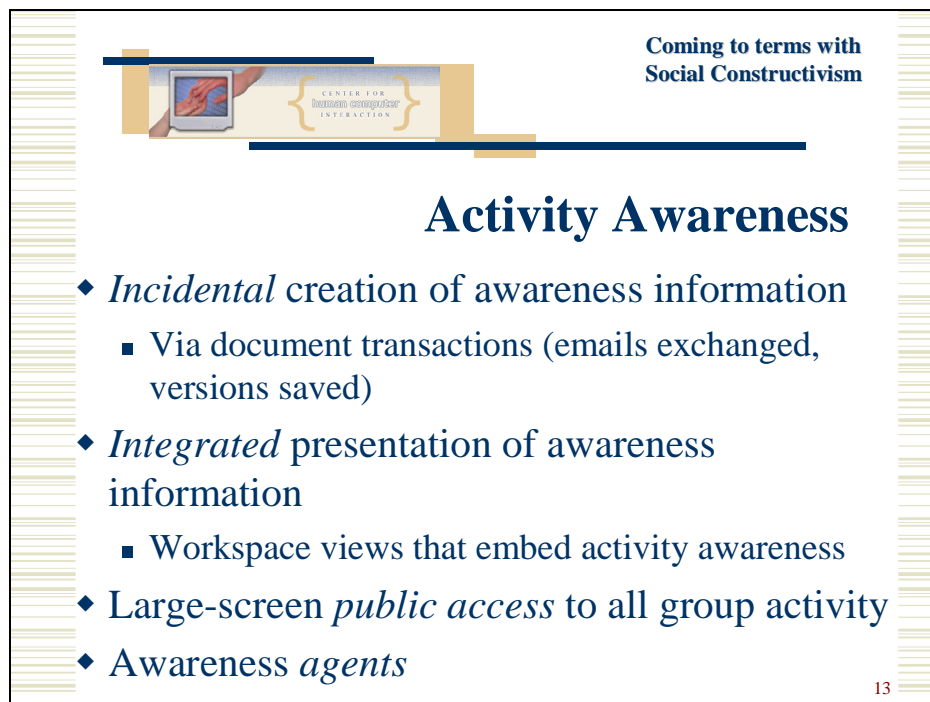
Figure 12

ACTIVITY AWARENESS

Activity awareness is our sense of the status, needs, and directions of an on-going collaborative project. It is more than a matter of who is looking at what data now. Physical proximity provides a great deal of transparent support for activity awareness. We believe that collaborative must do this too. We are exploring four directions: First, awareness information should be created incidentally; it should not become a further task for users. In our work, it is created as a side effect of ordinary document transactions. Second, awareness support should be integrated with work. In our designs, it is embedded in workspace views that encountered in carrying out primary tasks. Third, awareness information should be public, viewable at a glance. We are experimenting with larger-screen displays for this purpose. Fourth, the tasks required to maintain awareness should be delegated. We are exploring the use of agents as a mechanism for this.

Figure 13

VIRTUAL SCHOOOL 2

Our continuing development of the Virtual School, supported by NSF's "Information Technology Research" initiative, provides some examples of these directions. Some of the tools are familiar from the earlier Figure 5: Availability of collaborators, shared objects, a group chat tool. In this design more attention has been given to supporting emergent work organization. The to-do list in the lower left allows project members to keep track of goals.

More significantly, all project documents are organized in a time line view, which emphasizes the availability of previous versions, but also places the current versions in time with respect to deadlines (Carroll, Neale, et al., 2003).
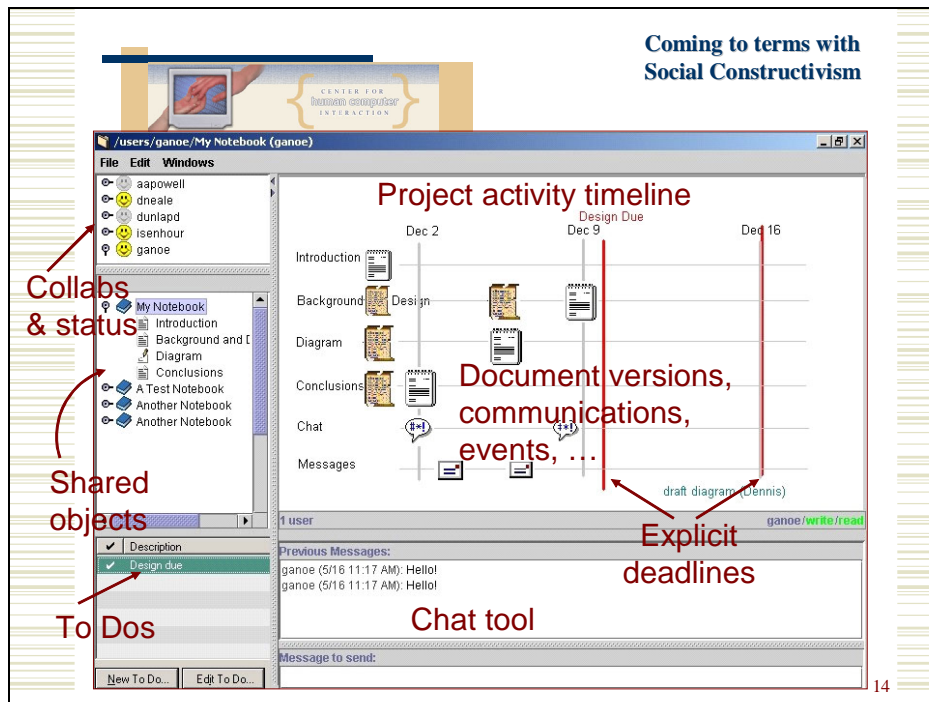
Figure 14

VIRTUAL SCHOOL: CONCEPT MAP

This is another view, with the timeline rolled up to make room for a document window, in this case a concept map representation of the content work of part of the project. Concept maps are very widely used in high school and university education. In future work, we plan to make the concept map a first-class representation of the project workspace, that is, an isomorphs of the timeline itself.

Figure 15

VIRTUAL SCHOOL: LARGE-SCREEN DISPLAY

The Virtual School 2 was fielded this fall in two classrooms. In February, we also fielded the large-screen, public interface that integrates across groups. This view consists almost entirely of timelines. An activity ticker at the top of the display cycles through the groups, providing a recent highlight of each group's recent activity. We are using it to explore the utility and other consequences of providing an integrative overview of all project activity in the connected classrooms.

A paper describing the Virtual School 2 system was submitted to the ACM UIST Conference (Ganoe et al., 2003 submitted).
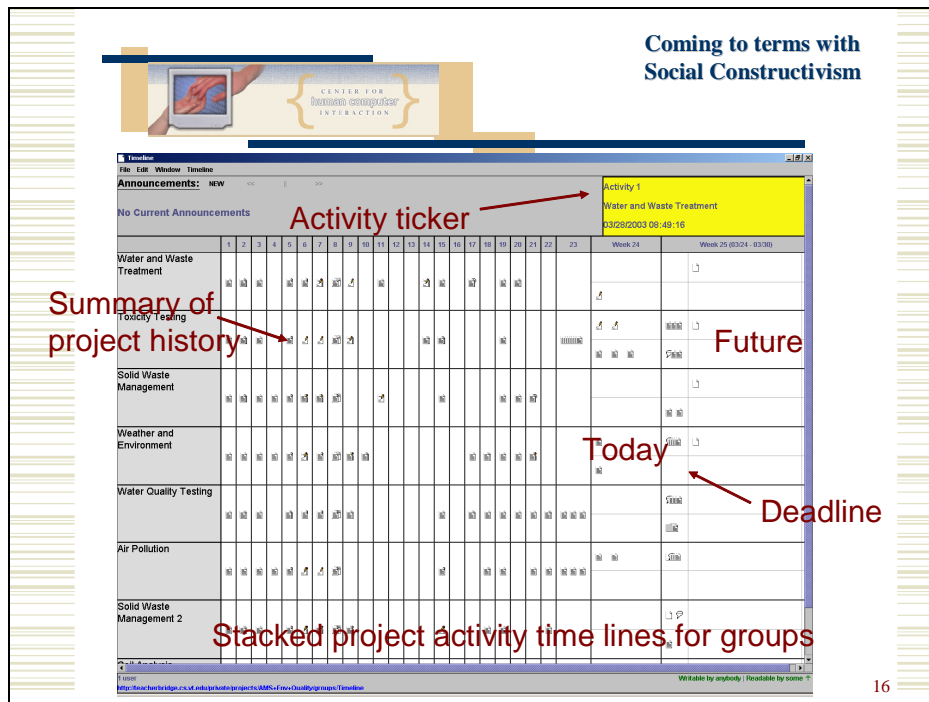
Figure 16

AWARENESS AGENTS

The fourth approach to supporting activity awareness that we are investigating involves limited agents that can carry out awareness-supporting missions such as "tell me when Captain Martin returns to the Wardroom". Such agents allow people to off-load some of the attention that would have been directed at maintaining awareness, but they also may enhance awareness through reminding and task engagement (see Farooq et al., 2002). As part of an ONR project, we have experimented with these techniques in the context of a Web-based MOO (multi-user domain) called MOOsburg (Carroll et al., 2001).
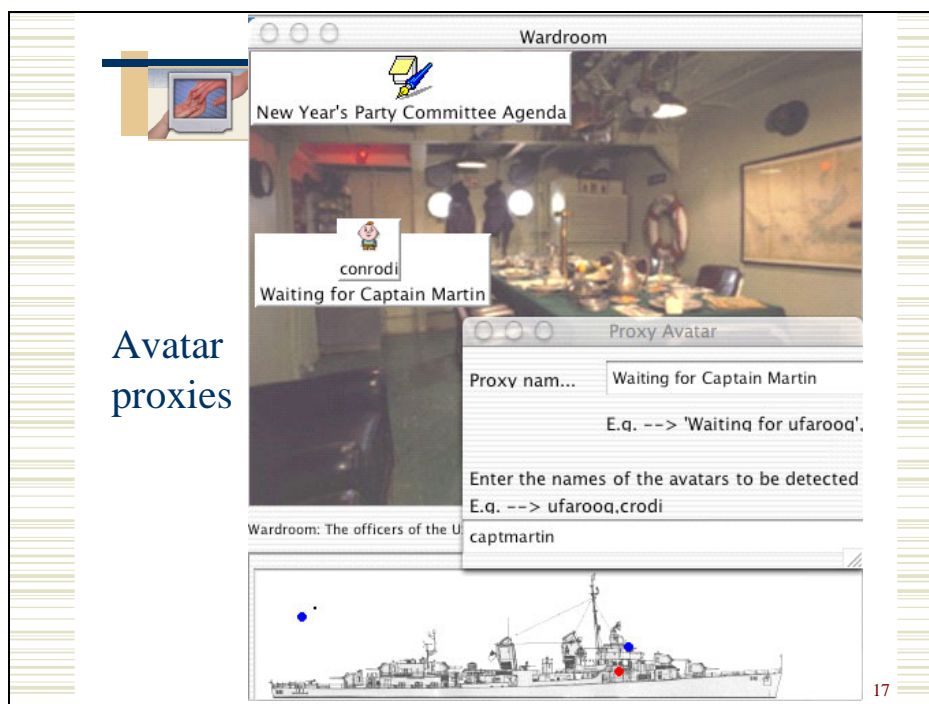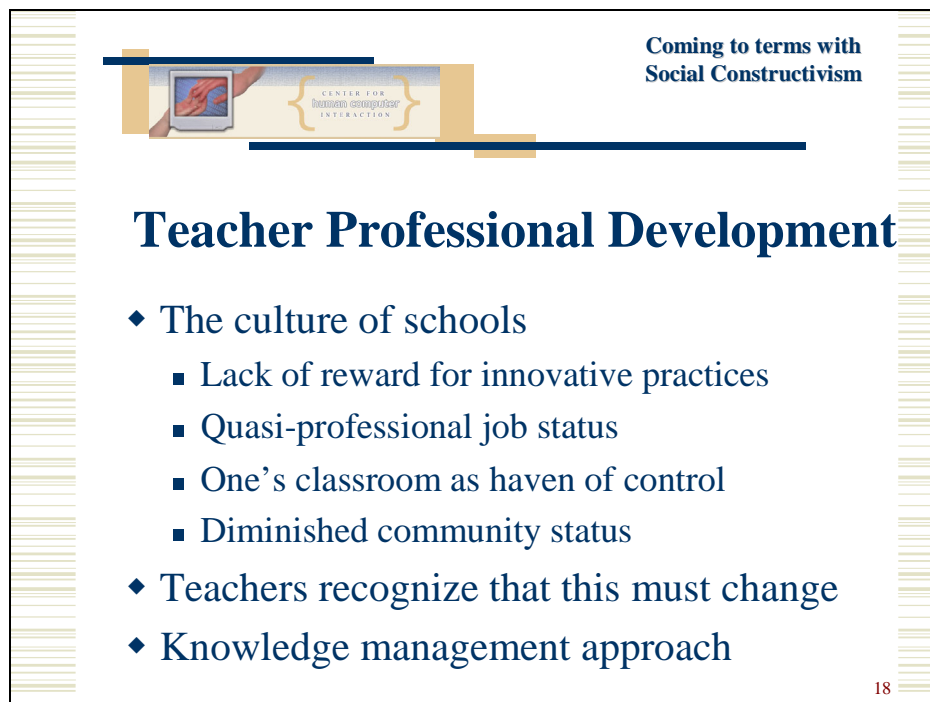
Figure 17

TEACHER PROFESSIONAL DEVELOPMENT

One's first impulse in educational research is to try to improve student performance. But the longer-term challenges and the bigger payoffs related more directly to teachers. Students stay in school 16-18 years; teachers stay 30-40 Years and impact hundreds of students.

Many problems in teacher professionalism derive from the fact that innovation in technology and practice is not regarded as standard operating procedure, or in some cases, rewarded at all. As mentioned earlier, teacher collaboration is not seen as a regular function of teachers. Teachers in service know these things must change, and many of them are looking for ways to change themselves.

We conceive of the current context in schools as similar in many respects to that in other organizations facing analogous transformations. With NSF support, we are investigating the use of knowledge management techniques and technology to support new approaches to teacher professional development.

Figure 18

LEVELS OF KNOWLEDGE SHARING

A simple way to look at this is that teachers need help in moving to "higher" levels of knowledge sharing. Today, they may share tangible resources. For example, in one school we worked with an enormous pendulum was shared; after all, who would even want a 30 foot high pendulum. It is more difficult to share plans, for example. Each teacher has a philosophy, has plans and resources, and may not want to expose these to others or to enter into a social process of negotiating adaptations.

One goal of teacher knowledge management is to move sharing to the level of prototypes-in-use, a term we use to describe pedagogical activities populated with data and experience. Prototypes-in-use are more personal, more evocative, richer, and more inviting to collaborators. (See Carroll, Choo, et al., 2003.)

Figure 19

EXAMPLE: DIFFUSION OF GOOD IDEAS

One approach we are using to try to facilitate higher levels of knowledge sharing is to help teachers develop their existing good ideas in a medium that makes the ideas more sharable. A teacher had run a reading/discussion activity for several years using command-line MOO software that presented a house with rooms that students could visit as they discussed books. Eventually, she was unable to run this ancient software.

We helped her to present the same basic activity using our CORK and BRIDGE software. This was easy to achieve and resulted in a far more refined user interface approach, as in figure 20. Moreover, it was extensible and reusable. As shown in the figure, this prototype-in-use can be recruited, modified, and re-purposed by other teachers for other similar activities.
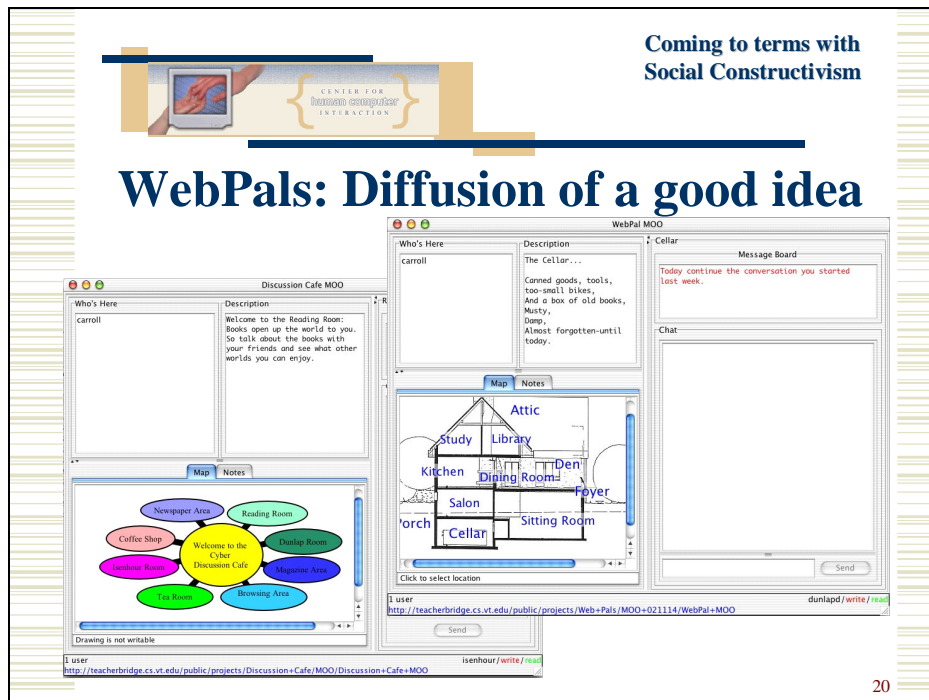
Figure 20

EXAMPLE: BRING STAKEHOLDERS TOGETHER

Another approach we have used is to support the development of new activities that bring a variety of local stakeholders together. The pandapas.org site is a good example. Pandapas Pond lies along the shared border of the two southwestern Virginia school divisions e are working with. Teachers from those school divisions, along with US Forest Service personnel, and others interested in the national forest can come together through this site, sharing activities and data.

Figure 21

NEW COLLABORATIVE ACTIVITIES

Whenever technology does not merely change the ways that we do things, it also presents us with new things to do. Part of our focus has been to investigate new collaborative learning possibilities that are enabled by the technologies we are investigating. For example, we are investigating new approaches to case-based learning in the context of a 3rd year undergraduate course in Usability Engineering, and we are investigating cross-generational informal learning through the collaborative construction and analysis of visual simulations of community dilemmas.

Figure 22

USABILITY CASE STUDIES

We have worked with industrial partners to create hypertext descriptions of several software development case studies. Students can browse the design documents and products, for example, the Web page designs for garden.com in Figure 23. They can study the entire design process from requirements analysis through activity design, information design, interaction design, documentation design and usability testing. They can carry out compare and contrast analyses of different case studies. This been highly successful in our own classes at Virginia Tech, as an adjunct to our textbook on usability engineering (Rosson & Carroll, 2001). We have recently begun a national test-bed project with NSF's Division of Undergraduate Education to further develop and investigate this approach.

Figure 23

CROSS-GENERATIONAL COLLABORATIVE LEARNING

Many aspects of our work have benefited from the technological and social infrastructure of the Blacksburg Electronic Village, a well-established, Web-based community network. Like many people, we noticed that children often grow up far from their own grandparents, but still in proximity to community elders. Senior citizens in Blacksburg are a well-organized and active group, and agreed to work with us on a project in which middle school children and seniors learn visual simulation programming techniques through designing simulations that depict community dilemmas (fighting in the school yard, noise in residential areas, bullying, and so forth). The projects are a forum for enhancing everyone's technology literacy and skills, and also for discussing different points of view regarding community issues. (See Rosson et al., 2002).

Figure 24

CACULATING COMMUNITY WELLNESS

One direction we are going with this project is to aggregate a sense of community wellness from the ensemble of community simulations pertaining to a variety of places throughout the community. We are imagining having people discuss not only isolated community simulations, but systems of contemporaneous simulations. For example, solving a conflict between residents regarding the noise created by a block party might balance the tension generated by a standoff among cliques at the middle school.
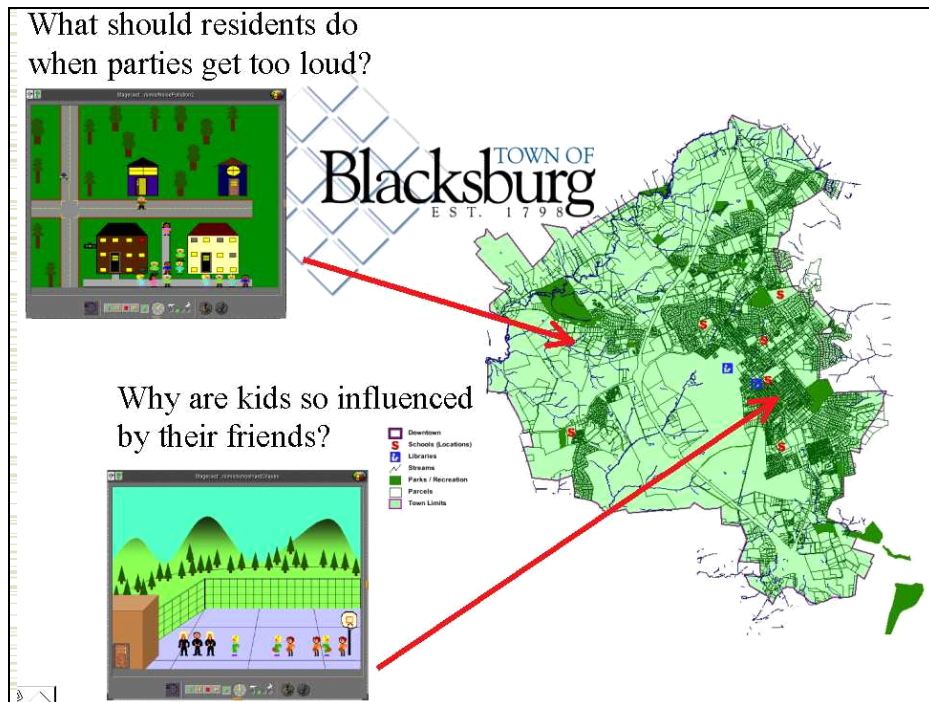
Figure 25

MOOSBURG

This vision exploits another piece of our collaborative infrastructure: MOOsburg, a Web-based MOO (multi-user domain) modeled on the layout of the actual town of Blacksburg, and navigated through use of a zoomable interactive map widget (lower right). Critical mass is a key limiting factor in creating rich information and activity spaces. Part of our vision is to have endeavors like the Virtual School, pandapas.com, the usability case studies, and community simulations play off one another in the shared community space of MOOsburg. (See Carroll et al., 2001).
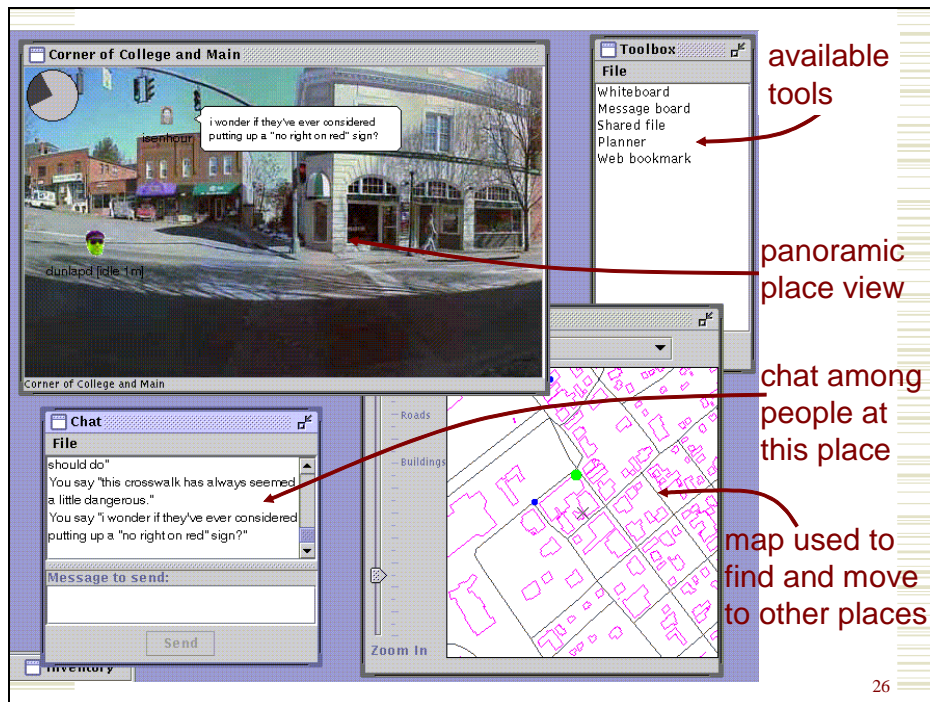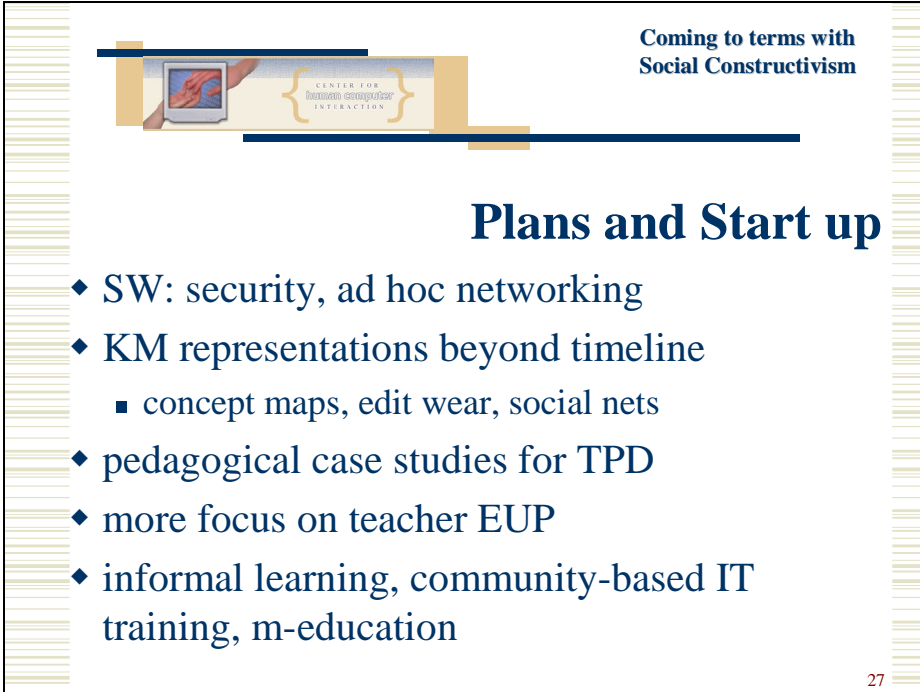
Figure 26

FOLLOW-ON WORK

In the immediate term, we are pursuing several further lines of technology development and empirical investigation. First, we are developing security and federation approaches, which are required for external implementations based on CORK and BRIDGE. Second, we are developing and assessing knowledge rubrics beyond the timeline that we explored in our recent Virtual School work (see Carroll, 2003, Rosson, et al.). Thirds, we are integrating the case study approach to project-based learning with our teacher professional development work, and focusing more attention on teachers as end-user programmers. Our vision requires that teachers directly create learning objects using BRIDGE and further tools. Finally, we are continuing to broaden our investigation of informal and community-based strategies to teaching and learning about Information technology.

Figure 27

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Technology Innovation Flight: Education and Training Technology Application Program

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Air Force Education and Training Command
Studies and Analysis Squadron/Technology Innovation Flight
Randolph AFB, TX

TECHNOLOGY INNOVATION FLIGHT: EDUCATION AND TRAINING TECHNOLOGY APPLICATION PROGRAM

This presentation is about an Air Force Education and Training Command (AETC) initiative called the Education and Training Technology Application Program (ETTAP).

Figure 1

INNOVATING FOR TOMORROW

ETTAP is all about bringing new technology into the classroom.

Figure 2

OVERVIEW

The briefing will cover the purpose of ETTAP; the process by which Air Force classrooms can obtain ETTAP funds; some examples of past and current projects, including a live demo of what we would consider the ideal; how we define a good project; the role of the project officer; how we evaluate new classroom technologies, some of the ETTAP programs that are going on nationwide; and finally, how you can reach the ETTAP program for more information.
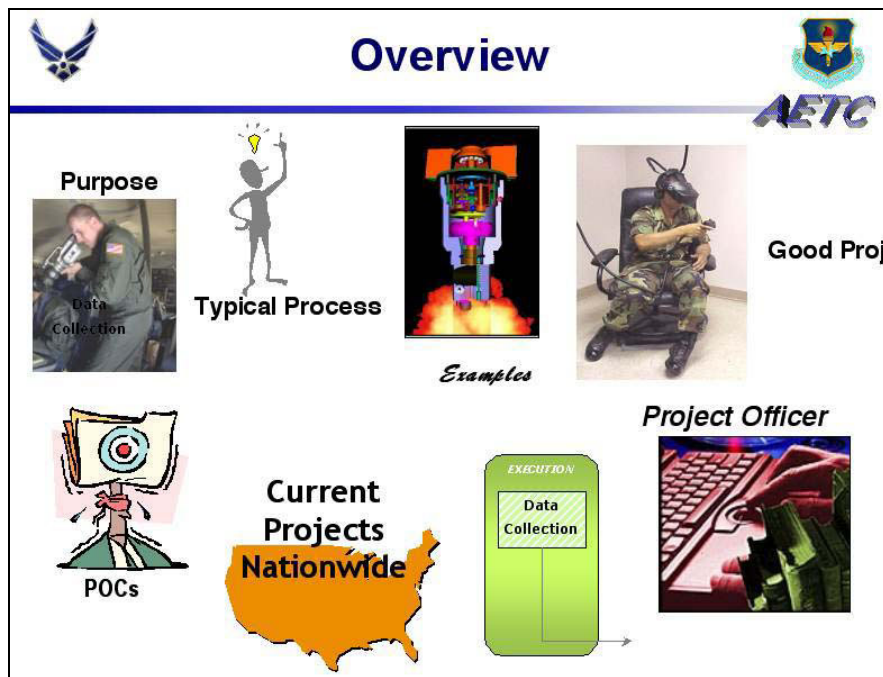
Figure 3

PURPOSE

       The purpose of ETTAP is getting new technology into the classroom fast. This involves identifying those technologies and then evaluating how well they do.
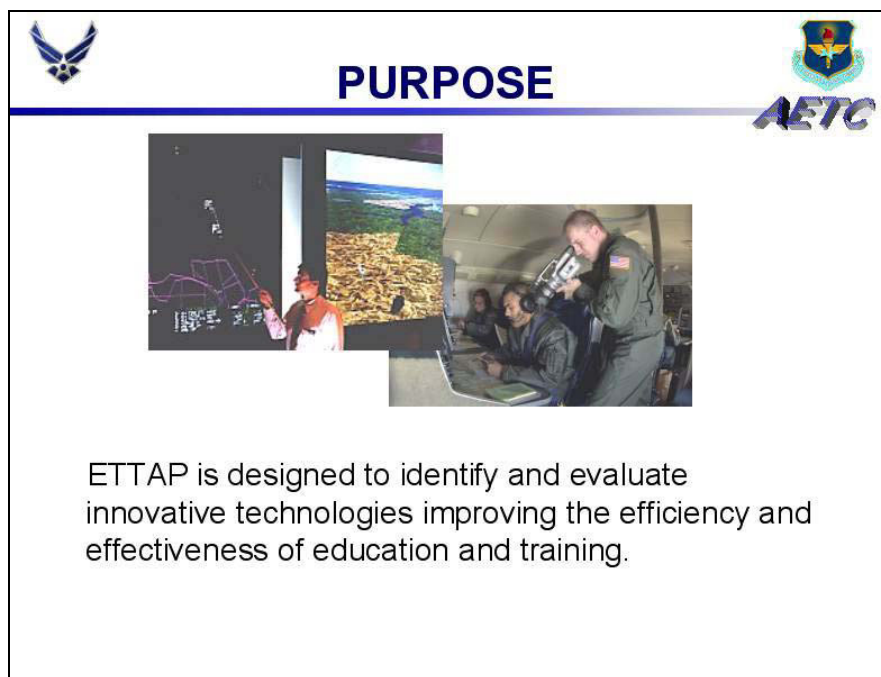
Figure 4

TYPICAL ETTAP PROCESS

Suppose there's a course at one of the twelve bases in the Air Education and Training Command; let's say it's a course on Leadership. And the instructor goes to a trade show or reads a journal and discovers a new technology – a computer game, for instance – that he thinks will help his students learn better/faster/cheaper. Well, ETTAP gives him the seed money to buy it. So, he purchases 30 copies of this computer game and gives it to his students. We then spend the next six months to a year to see how it pans out. Does it, in fact, help students to learn Leadership better, faster, or cheaper? If it does, then great. If not, well – at least we tried. And we didn't waste a lot of time and money in the process.
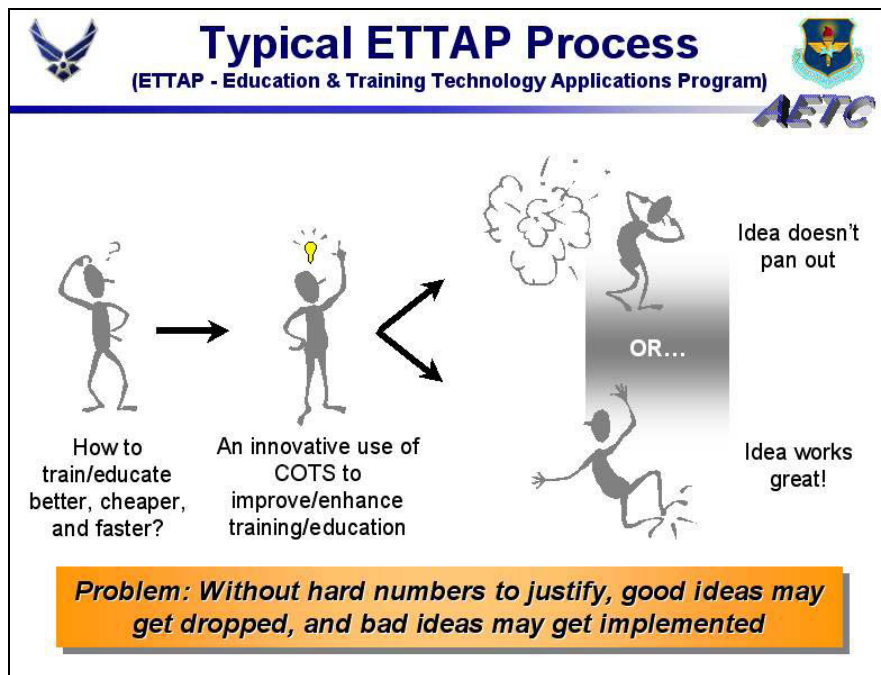
Figure 5

MICROFLIGHT

Here are some examples of ETTAP projects past and current to give you an idea of what I'm describing.

MicroFlight is a PC based flight simulator used to familiarize new pilots with flight maneuvers. It helped T-37 pilot trainees at Laughlin AFB TX become proficient faster.

Figure 6

AIR TRAFFIC CONTROL (ATC) VIRTUAL REALITY

The Air Traffic Control Virtual Reality system helped trainees at Vance, Altus, Luke, and Randolph AFBs simulate extreme hazards which they would rarely, if ever encounter in real life.

Figure 7

COST EFFECTIVE VIRTUAL REALITY

Cost Effective Virtual Reality (CEVR) is VR without the headset. What you see is a three dimensional object like a hologram that jumps out at you from your PC screen. Instructors at Sheppard AFB TX used CEVR to teach the components of the Mark 84 bomb.

Figure 8

F-15E VIRTUAL REALITY

Also at Sheppard, the F-15 Virtual Reality system does require a headset. It teaches students maintenance on the F-15E fighter aircraft and saves the schoolhouse the considerable expense of having the actual jet on hand for the students to train on.
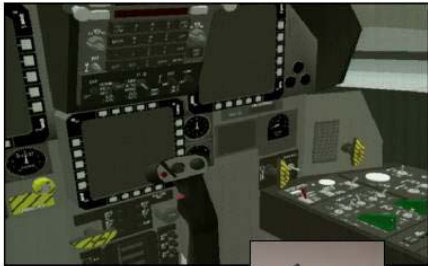
Figure 9

SCHEMATIC POWER BROWSER

Schematic Power Browser is one of our most widely adopted projects. It allows instructors to show complex schematics on a Smart Board and manipulate those schematics by hand, taking them apart, moving them around, and magnifying them at will.

Figure 10

ELECTRONIC CLASSROOM

We built a comprehensive multimedia electronic classroom at Vandenberg AFB CA, complete with PCs, LAN, Internet connectivity, smart boards, overhead projection, online testing, and instructor control of individual student workstations. It enables Space Officer trainees to receive all their instruction and all their exams electronically,
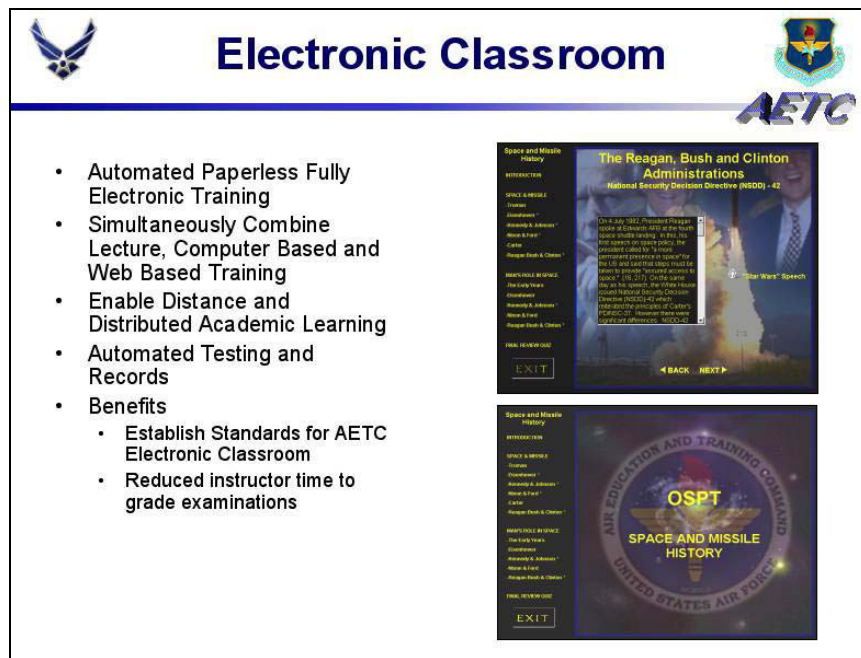
Figure 11

ELECTRONIC BOOKS

Students at Keesler AFB use electronic books to store 80,000 pages worth of hardcopy textbooks, manuals, and regulations in one lightweight convenient device. One of the best features of E-Books is update. In the past, if Keesler instructors wanted to make a change in a student manual, however slight, they had to wait 5 ½ weeks for the print shop to create new hardcopies, and pay an average of $30 per document. With E-books, updates can be accomplished in seconds versus weeks, and the cost is free.
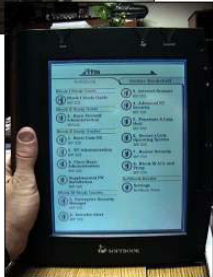
Figure 12

N'GRAIN EXAMPLE

Finally, here's an example of what we would consider an ideal ETTAP project. It's a commercial-off-the-shelf – or COTS – product that allows an instructor to display on a big screen, a three dimensional view of any hardware or piece of equipment.

- He can rotate it to show how it looks from any angle.
- He can disassemble it piece by piece, and then reassemble it.
- Or, he can challenge his students to reassemble it themselves.
- He can zoom in to show closer views.
- He can even cut it down into cross sections in order to show what it looks like inside.

This example is a watch. But the demo also includes a rifle, an aircraft, and a bomb. Of course, the instructor can choose whatever piece of hardware he wants.

The total cost ranges from about $15,000 to $50,000 if you want the contractor to build a whole course for you. But this is a lot cheaper than having an actual aircraft to demonstrate on. Or, it's a lot safer than having an actual bomb.

Figure 13

A GOOD ETTAP PROJECT

So, what makes a good ETTAP project? We ask ourselves these questions:

- Is it new technology? Is it off the shelf?
- Does it make learning better, faster, or cheaper?
- Can we test it out in a year?
- Can we use it for other classes?
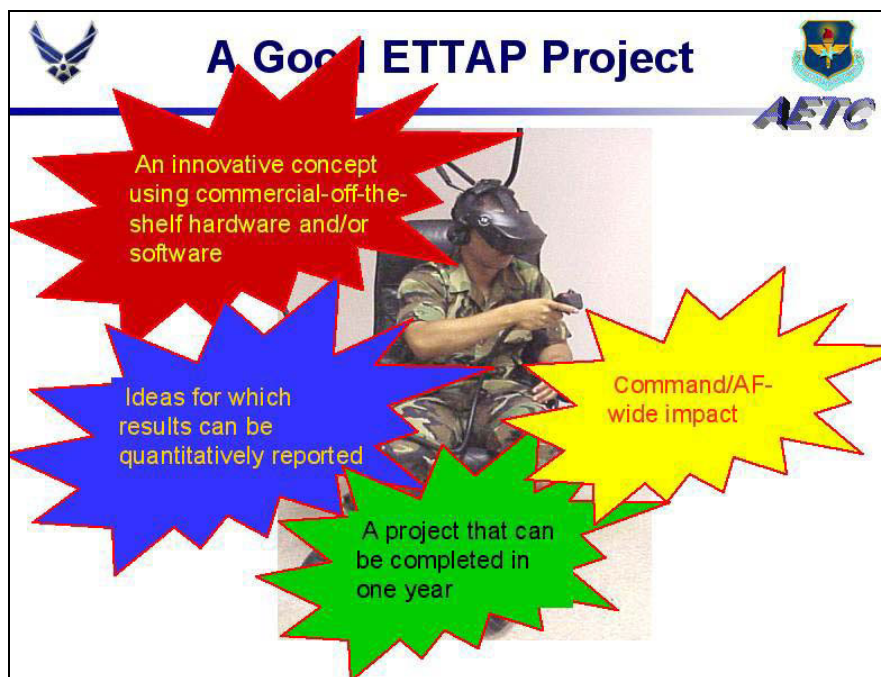
Figure 14

PROJECT OFFICER TASKS

If the answer to these questions is "yes," then here's what the classroom instructor need to do.

1. Submit a one-pager to HQ AETC (pass out SF)
2. If we approve it, then, we'll ask you to go into more detail
3. Help us test it out in one or more of your classes
4. Every three months, tell us how things are going
5. Then, at the end of a year, tell us how things worked out

Figure 15

STUDIES AND ANALYSIS TASKS

Evaluating each project takes about a year and requires several stages of detailed planning. Once we think we're ready, we start collecting data from classes of actual students in AETC. In the end, it all comes down to a final report, which declares whether or not the technology was effective.
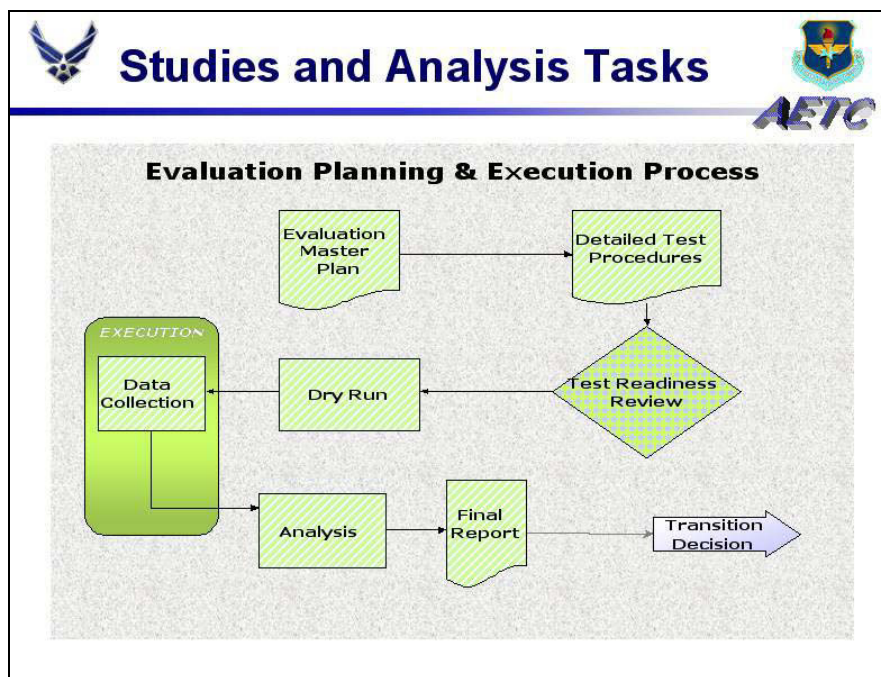
Figure 16

CURRENT ETTAP PROJECTS

This is just a big picture view of all the ETTAP projects we have going on nation-wide.
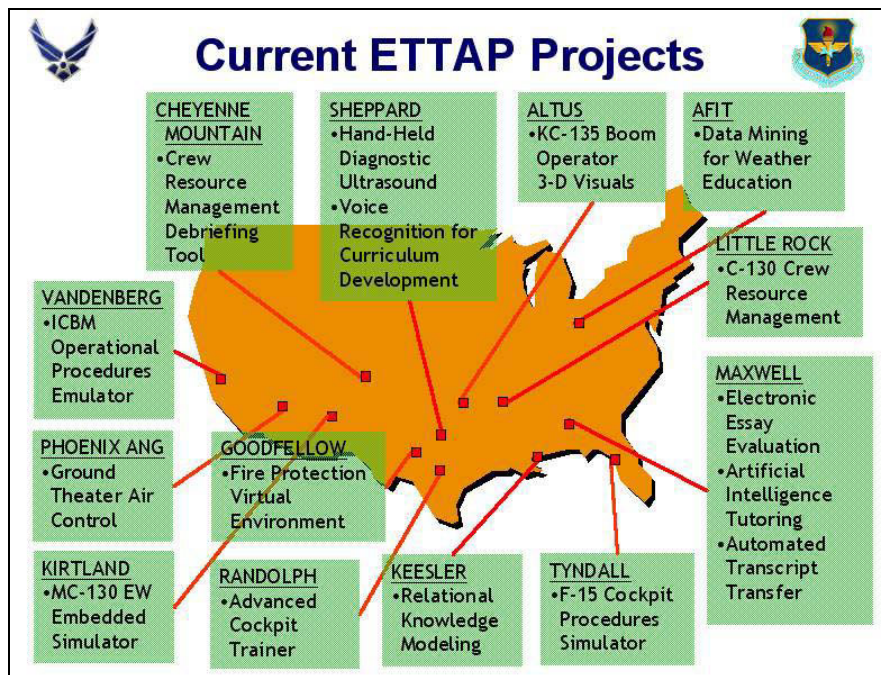
Figure 17

ETTAP POCs

And here are some contact points for further information.

Figure 18

IMAGINATION

Imagination – that's what the ETTAP program is about.
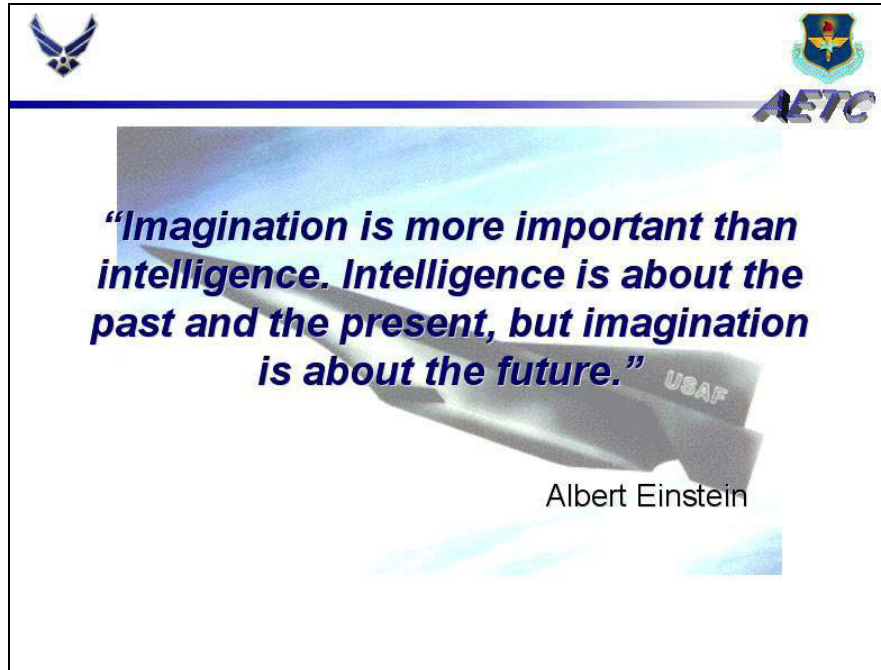
Figure 19

Figure 20

AETC Technology Integration and Development

Capts. Garald Egts and Phong Nguyen
HQ AETC/XPRT
Air Education and Training Command
United States Air Force, Randolph AFB, TX

Figure 1

Figure 2

Overview

- Mission and Responsibilities
- Mission Areas/Programs
- Education and Training Technology Application Program (ETTAP)
- Technology Transition
- AF Battlelab Support/Other Initiatives
- Generalized Operations Simulation Environment (GOSE)
- Points of Contact

Figure 3

Mission/Responsibilities

Improve the effectiveness and efficiency of AETC training and education by identifying, evaluating, and advocating new technological applications

- Explore the intersection of learning and technology
    - Plan/Advocate for technology insertion and innovative practices
    - Fund conceptual applications
    - Test ideas, concepts, and technologies
    - Provide quantitative and qualitative ROI assessments
- Influence program managers and senior leaders
    - Connect technologies (tools) to solve user problems
    - Program Managers determine their program requirements and whether the interventions "fit"
    - Senior leaders make the programming trade-offs

Figure 4

Mission/Responsibilities

- AETC focal point for AF Battlelabs, Science & Technology, Modeling and Simulation (M&S)
  - Represent AETC at OSD, DoD and USAF level meetings
  - Keep program managers abreast of changes
  - Maintains AETC resources in AF M&S Resource Repository
- Provide technology education to AETC units
  - Functional Utilization and Training Workshops
  - Crossfeed technological advances/achievements
- Gather internal educational and training requirements
  - Identify and document command's inefficiencies
  - Seek cost-effective technological solutions

Figure 5

Mission Areas/Programs

- Recruiting/Accessions
- Policy/Programming
- USAF Chief Scientists Group
- Aircraft Maintenance and Munitions
- Logistics Training
- Combat Support Training
- Modeling/Simulation
- Communications and Information Training
- AF Battlelabs Liaison

- Education
- Technology Planning
- Air and Space Training
- Medical Training
- Flying Training
- Classroom Technology
- Education and Training Technology Application Program (ETTAP)
- Applied Technology Council

Figure 6

Figure 7

Figure 8

Overview

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- Generalized Operations Simulation Environment (GOSE)
- Points of Contact

Figure 9

ETTAP

(ETTAP - Education & Training Technology Applications Program)

- Command's innovation process (AETC Instruction 36-2218)
  - Identify and evaluate new technologies to solve education/training inefficiencies and deficiencies
  - Provide timely adoption and integration of proven technologies, capabilities, concepts, and processes into AETC planning and acquisition activities, organizations, and operations
- Harness new technologies to provide better, faster and cheaper training
- Since FY 2000: 160 projects proposed, 39 approved

Figure 10

Figure 11

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Figure 13

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Figure 22

Figure 23

Figure 24

Figure 25

Figure 26

AF Battlelab Support

- AETC provides AF Specialty Code qualification training to all operational AF personnel
- As Battlelab initiatives are developed and tested, the AF must understand the impact that these initiatives will have on training and its associated costs
- AETC assists AF Battlelabs in determining these training impacts

Figure 27

Why?
The Innovation World

Connecting the Dots For ...

Results - Lessons - Feedback

Improved Combat Capability

Educate - Train - Exercise - Execute

Wargame

Experiment
JEFX

Initiative
Battlelab

Figure 28

Figure 29

Figure 30

Figure 31

Figure 32

Figure 33

Figure 34

Figure 35

Figure 36

Figure 37

Figure 38

Points of Contact

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Figure 39

Standards-Based Approach for E-Learning Technologies

Jerry West
Advanced Distributed Learning Co-Lab
Alexandria, VA

Figure 1

Figure 2

Figure 3

Figure 4

Figure 5

Figure 6

Figure 7

Figure 8

Figure 9

Figure 10

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Figure 28
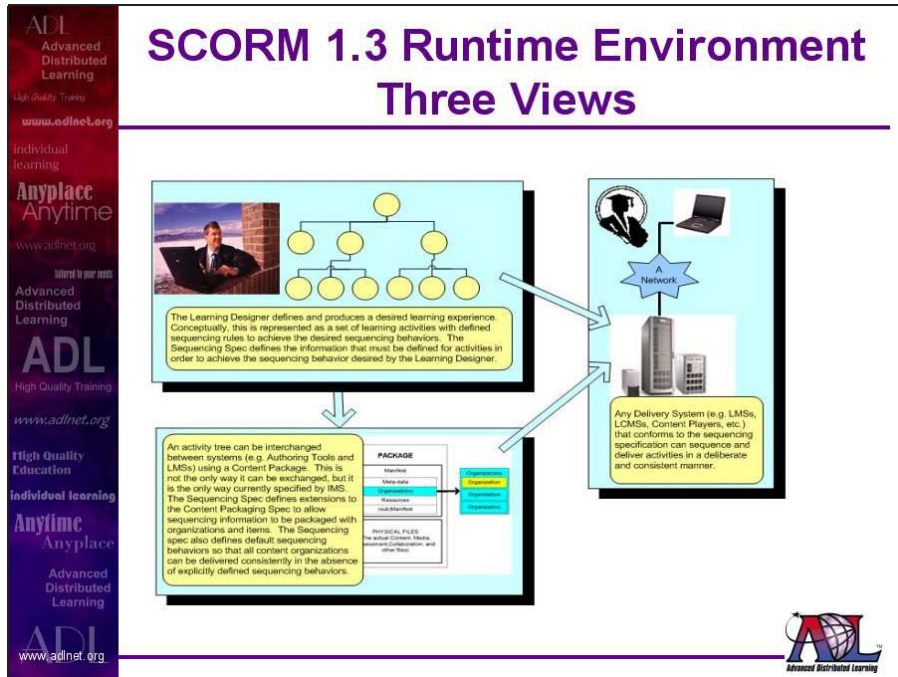
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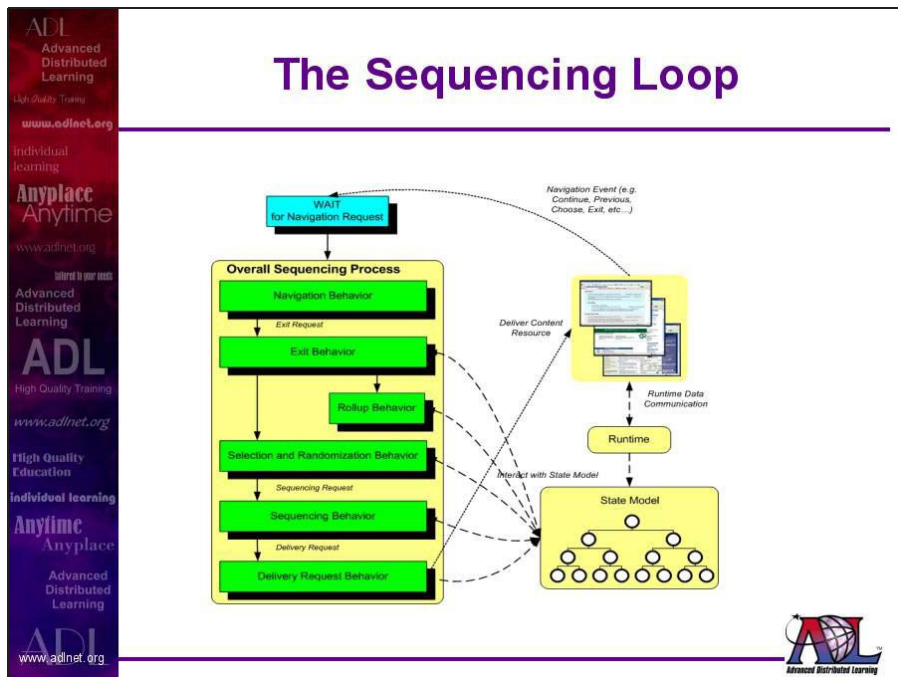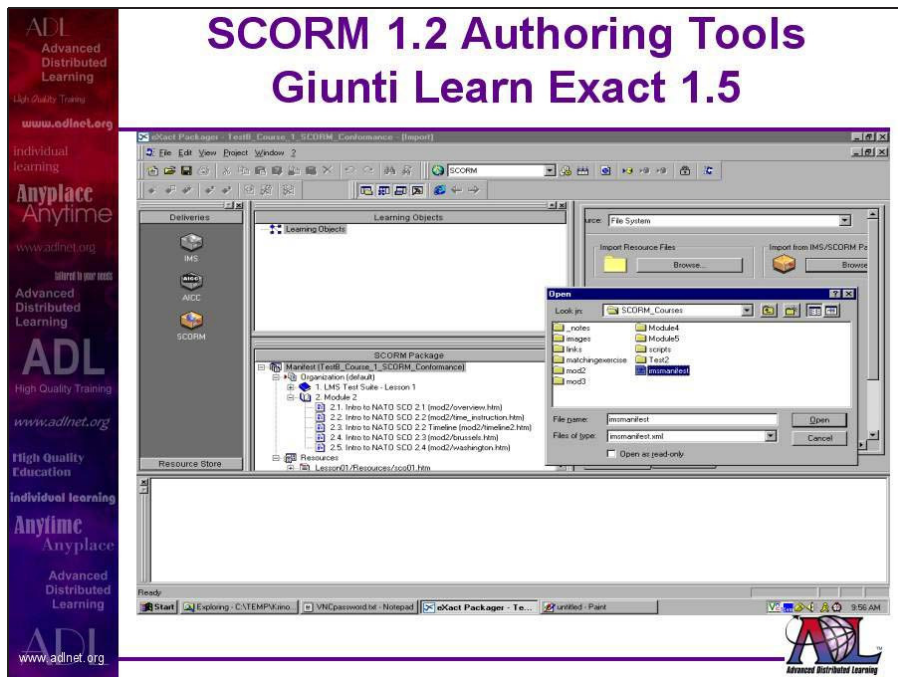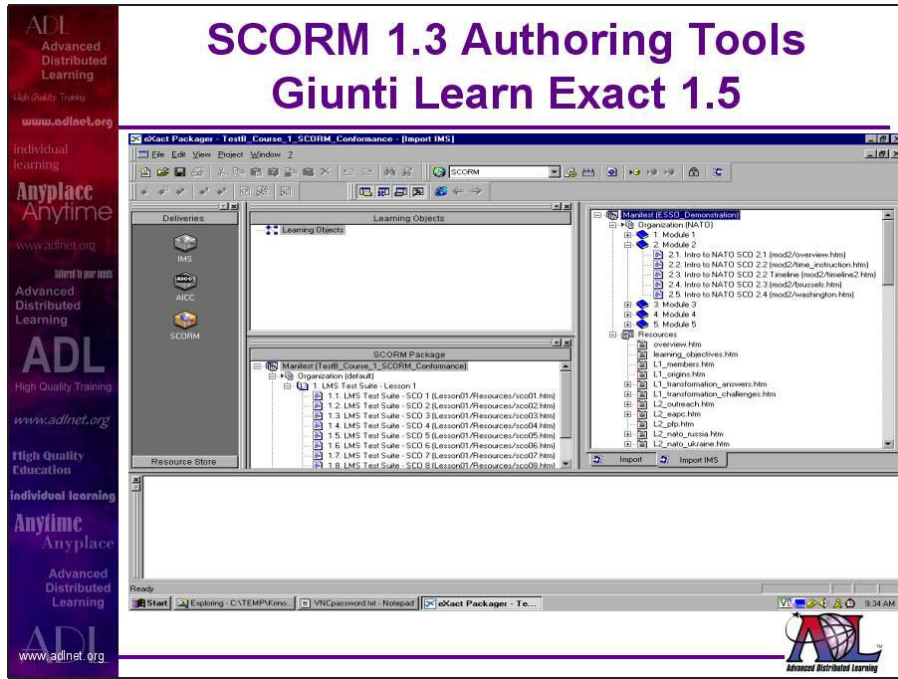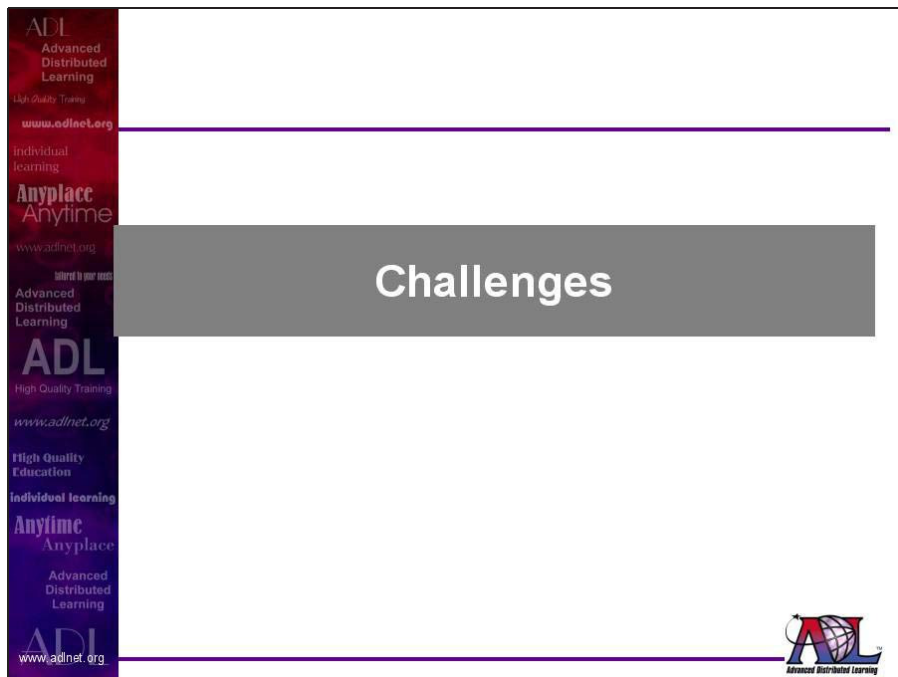
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Figure 31

Figure 32

Figure 33

Figure 34

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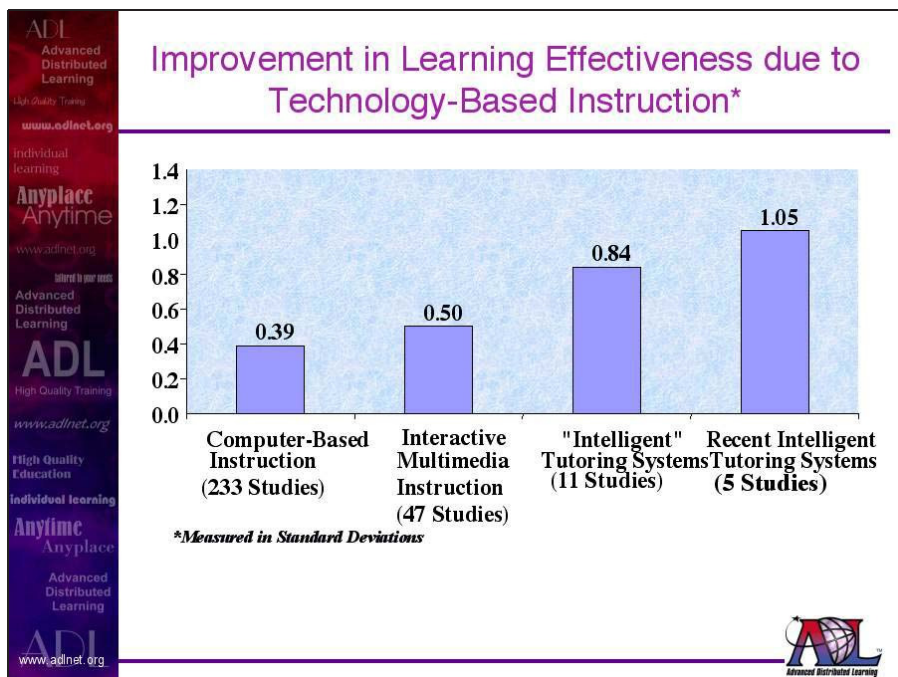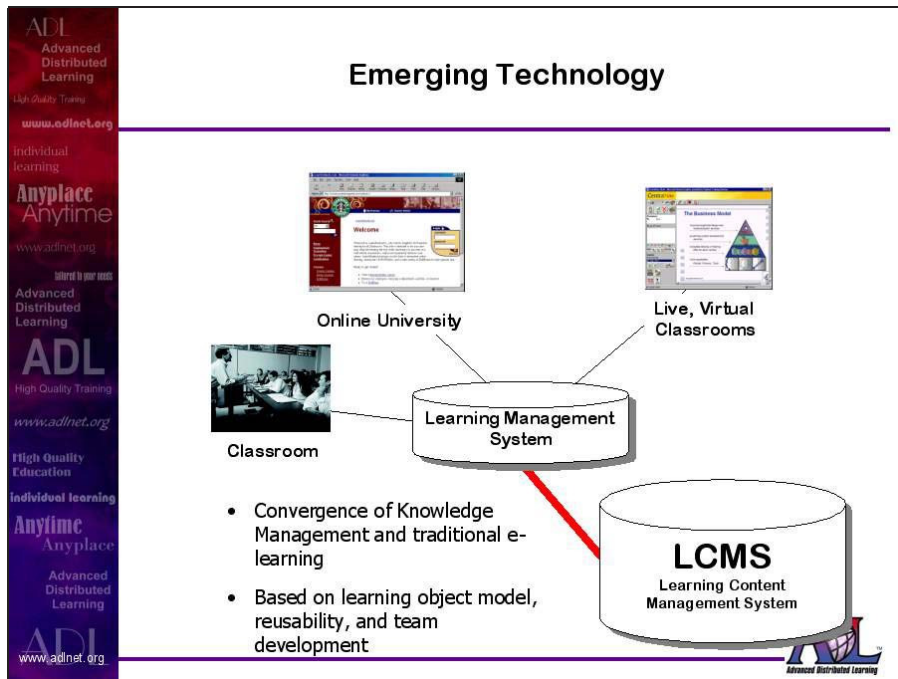
Figure 35

Figure 36

Figure 37

The Scalability and Usability of Asynchronous Learning Networks

Shawn Foley
Pennsylvania State University
York, PA

The Scalability and Usability Of Asynchronous Learning Networks

Shawn Foley
Pennsylvania State University

"Technologies and growing pressure to provide quality learning
experiences on-campus, are transforming higher education."
(Anderson, Garrison, 1998).

Figure 1

Objectives

- Determine the relevance to the audience
- Discuss challenges encountered
- Example: Take a look at a course
- Present the results of a quantitative benchmarking study
- Discuss the importance of pedagogy to curricular design

Figure 2

Objectives

- Examine technology tools and services that allow the course to be administered
- Examine some methods in which our course was designed and developed
- Provide recommendations
- Questions/Discussion

Figure 3

Relevance to the Audience

Figure 4

Example: Brief History and Unique Challenges

- The School of IST: Penn State
- IST Program Focus
    - Educate students to be leaders and problem solvers
    - Educate students to understand and apply technology
    - Sensitize students to the people and policy issues
    - Educate students using real-world problems
    - Engage students in the realities of information technology in the workplace.
    - Put the students in teams to deal with their exploration, and push them to build their oral and writing skills.
- Knowledge Acquisition, Generation, and Integration

Figure 5

Common Challenges

- Reaching several stakeholders and educational institutions
- Reaching a broader student audience
- Decreasing instructor workload
- Designing for various learning environments
- Acquiring and Managing Content
- Course Evaluation and Revision
- Maximizing benefits of technology

Figure 6

Example: Pedagogy

- PBL Methodology and Hands on Skills
- Combination of theoretical approaches
  - Cognitivist/Constructivist
  - Behaviorist
  - Collaborative Learning/Team-based
  - Guiding and Generative Learning
- Solution: Hybrid Approach (Mixing online learning with important traditional residence based components)

Figure 7

Example: Course Tools and Learning Support Services

- Allow for modularity and multiple delivery
- Vary components depending on instructors preferences
- IST 220: Telecommunications and Networking
  - Course Interface
  - Course Communication Space (LMS)
  - Communication Roadmap
- Solutions Learning Exchange

Figure 8

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Figure 17

Figure 18

Comparing Models:
Traditional Lecture

- Time on task for a traditional residence based course (4 + hrs.)
    - 45-50 Students, Instructor: Lecturer, Presenter
    - Class meets 3 times a week for one hour
    - Discussion and lecture occurs in class
    - Class meets 1 hour a week for the lab
    - Problem solutions need to be graded
    - Labs need to be graded
    - Module quizzes are graded automatically, scores need to physically posted, tests are handed back

Figure 19

Comparing Models:
Asynchronous Course

- Time on task for an asynchronous rolling enrollment course (3 + hrs.)
    - 45-50 Students, Instructor: Mentor, Guide
    - Class never meets, communication occurs virtually
    - General communication, 1 hour a week
    - Discussion activities, 2 hours a week
    - Problem solutions need to be graded
    - Labs need to be graded
    - Module quizzes are graded automatically scores are posted electronically

Figure 20

Pedagogically Sound Technology Solutions

"At the foundation of any effective online education or training is the understanding of present pedagogical practices. Whether those practices have been in place for years or they are brand new."
(Foley, 2002)

- Pedagogy is the foundation
- Instructional strategies should support your pedagogy
- Technologically sound solutions should support the instructional strategies and ultimately your pedagogy

Figure 21

Step 1: Instructional Design

- Analysis (Needs, Learner, Context, Task)
- Design – Content is King
- Development – Infrastructure is god
- Implementation – Infrastructure is god
- Evaluation – Is it working? Can it be improved?
- Revise Accordingly

Figure 22

Step 2: Customized Process and Methodology

- The Key is Process and Methodology
- Should be customized to meet the needs of the institution
- Should be based on strategies and models that are already proven valid and reliable
- Should be modular, scalable and replicable
- Should increase the effectiveness of present teaching as well as save time and money

Figure 23

Instructional Design: Course Design and Development

- Learner Analysis and Learner Profiles
- Project Plan/MOU
  - Goals and Sub-Goals
  - Justification Statement (Establish Need)
  - Collect Background Data/Plans For Future (How has the course been taught in the past what should change?)
  - Assumptions (target audience, delivery structures, possible educational context and delivery strategies)
  - Key Challenges
  - Resources, Timeline and Budget

Figure 24

Instructional Design: Course Design and Development

- Content Outline (Content is King)
  - Instructor Books, Websites, Other Resources
  - Subject Matter Experts (Instructors)
- Develop Content Collection Strategy
- Review Content in Chunks
- Brainstorm Instructional Strategies (focus on tough concepts)
- Development (flowcharts, storyboards, rapid prototyping, Going Live!, Evaluation)

Figure 25

Beneficial Technologies

- Content Management Systems (Databases)
  - Content is King
  - Infrastructure is god (manage content)
  - MySQL/PHP, FileMaker Pro, DB2, Oracle, Access
- Learning Management Systems
  - Angel, WebCT, Blackboard, First Class
  - Focus on the learner to learner, learner to instructor, and learner to content communication
- The Web

Figure 26

Recommendations

- Treat Content as King
  - Based on Objectives
  - Chunk in terms of Learning Objects
  - Chunk in terms of Information Objects
  - Develop content without considering the final outcomes or instructional strategies
- Plan for scalability and modularity
- Technology is constantly in transition plan accordingly

Figure 27

Recommendations

- Focus on learner
  - Education and learning should not suffer
  - Communication is key
  - Be aware of digital divide issues
  - Be sensitive to perceptions
- Learner and Instructor support is available
- Develop a process and a methodology
- Take things one step at a time
- Remain flexible
- Be organized and document everything

Figure 28

Addressing Learning Challenges with Advanced Technologies

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OVERVIEW OF LEARNING CHALLENGES

In framing the question, "How can advanced technologies transform learning", we take a broad perspective, looking not only at how learning technologies can be improved but also asking how advanced technologies might change what we need to know, how we access knowledge, and how we work together. Given this broad perspective, we choose a number of technologies being developed at IBM that, we believe, have the potential to powerfully impact learning.

The technologies we discuss are organized by how they might address important learning challenges (listed below in Figure 1). These include the challenges of transforming tasks to better fit our competencies; better situating knowledge so that what we need to know is "ready to hand"; reducing language as a barrier in cases such as illiteracy or when translation is required; finding and indexing relevant information for the solution of problems, including video and other rich media; gainfully collaborating with others; and reflecting and learning from our experiences. This list is not meant to be exhaustive (e.g., numeracy is missing), but to be broad and representative. Further, it highlights areas where IBM and others have made significant recent advances.

1.	Transform	Revise how a task is performed.
2.	Situate / Transfer	Recall and place in context the knowledge needed for the problem at hand.
3.	Language	Literacy. Translation.
4	Reflect	Learn from experience. Formalize what you know so it can be shared with others.
5	Search / Index	Ability to find the information you need. Create indices so rich media can be retrieved.
6	Collaborate	Find people to work with to solve a problem. Devise mechanisms that enable people to work together. Revise social systems for improved performance.

Figure 1

TRANSFORMING THE TASK: 2D FACE TRACKING

Technologies transform how we accomplish tasks through the coordination of our memory, cognition, fine motor skills, vision, etc. A dramatic example of one such transformation is provided by a system that allows quadriplegic users to access computer applications (see Figure 2). A face tracking system allows them to move the screen cursor by moving their nose, replacing the need to manipulate a mouse with their hand [1]. Clicking and double-clicking are accomplished by voice commands. In this way the technology transforms the control of the mouse from hand to nose and voice. This technology transforms what actions are needed to accomplish a task. The implication is that educators become, in part, designers who must decide which actions should be used to accomplish what tasks. Of course, such decisions can have dramatic ramifications. Over two millennia ago Plato (writing in the voice of Socrates) worried that the replacing memorization with the use of written texts would diminish his students' powers of memory. Indeed writing is believed to have resulted in reduced memory in literate societies, as it promotes a dramatic reorganization of cognition, memory, and perception in the accomplishment of many tasks and, in the competencies and habits of those facilities. Thus, through our advanced technologies we reconfigure our role in the accomplishment of tasks and thereby what needs to be learned and performed.

Figure 2

SITUATE INFORMATION USING "THE EVERYWHERE DISPLAY"

A primary way to help learners is to provide situated knowledge. For example, contrast driving assisted by a road map versus road signs. Using the map involves tracing a route on it and then aligning that route with one's current view (e.g., figuring out where one is on the map). In contrast, road signs are embedded into our view of the world. The often difficult step of coordinating representational frames is skipped. The Everywhere Display is a powerful technology that can situtate a wide variety of information by overlaying it on (or augmenting) the world [2]. In effect, this creates an interactive world of signs to guide our actions.

The Everywhere Display accomplishes this by projecting its images onto an arbitrary surface and then recognizing our gestures as we interact with the images and virtual controls it projects. For example, in Figure 3, a picture is being dynamically drawn on a conventional table. Thus, the use of projection and gesture recognition transforms the table into an interactive device. The picture is being drawn as pointillist drawing using M&Ms where the computer guides the user in the placement of the M&Ms. At the moment shown below, the user is guiding what portion of the picture should be projected by a sweeping gesture. The computer's visual analysis of this gesture is shown inset in the lower left. Thus, the ordinary interaction via keyboard and mouse has been replaced with gestures that are recognized using advanced vision algorithms and the ordinary screen has been replaced by projecting images onto arbitrary surfaces.

In this way the physical world has been painted over with a layer of information—the computer has situated its information into our perspective. In a word the world has been *infomated*. This technique can have dramatic implications for learning and performance. Imagine asking for help in using a copy machine and that help being displayed directly on the machine, animating what should be pressed and recognizing and correcting your actions as you try to comply. This advance is very significant since we know a primary stumbling block to successful use of what has been learnt is applying it to novel situations (the so called "transfer problem"). The Everywhere Display shows how that transfer can be assisted as computers augment the world with layers of information.

SITUATE USING "PHOTOGRAPH BASED LOOKUP" IN INFOSCOPE

Most categorizing systems use some sort of index to organize their contents. For example, books in a library are organized by the Dewey Decimal system. Indices are very powerful because they allow us to quickly look things up and to organize things with respect to one another. But they also introduce learning issues in that they pose a level of separation between the thing being sought and the means of asking about it. For example, in classifying a tree the taxonomic key might ask you to whether it has leaves or needles. These decisions become a problem when it is difficult to describe what you see in terms of the key. In contrast, the InfoScope system uses the world itself as the index for the information you're seeking [3]. Using a handheld computer you take a picture of your surroundings, say a building. It wirelessly transports it to a server along with your current geographic coordinates (using a global position system) and it looks it up in a database and returns information about that building (e.g., when it was built, what it looked like originally, its architecture plans). Alternatively, InfoScope can translate signs. For example, in Figure 4, below the signs have been translated revealing the name of the train station. This means of information lookup makes the world itself an index to our information stores, rather than using an intermediate representational language.

Figure 3

LANGUAGE LEARNING ENVIRONMENTS

The shortfall of skilled workers needed for the global knowledge economy has fueled education and training programs delivered through schools, government agencies, and industry. However, access to these resources requires a base of developed literacy skills often lacking in the very populations they target. When scaled to meet the demand of the numbers of needy students, the costs of instructor-led solutions become impractical, inviting a search alternatives based on technology.

Enormous gains in processor speed have combined with the development of powerful algorithms to deliver automated speech recognition (ASR) technologies effective enough to support computer-based language and literacy tutors. For example, a team from IBM Research re-purposed IBM's dictation-oriented ASR by equipping it with an acoustic model appropriate for six year-olds, creating a usable, provably effective reading tutor [4].

Extending this work by using a web-based architecture (see Figure 5) to centralize ASR resources and instructional management will yield several advantages:

- A centralized architecture enables matching users with the acoustic model that best recognizes their speech, enabling optimization for linguistically diverse groups
- Background data collection supports the development of individualized acoustic models to optimize speech recognition for each learner
- Centralized session management will enable learner to collaborate, exploiting validated approaches such as reciprocal teaching [5]
- Workflow-governed collaborative content development strategies will quickly yield large amounts of sharable narrative and expository training materials.
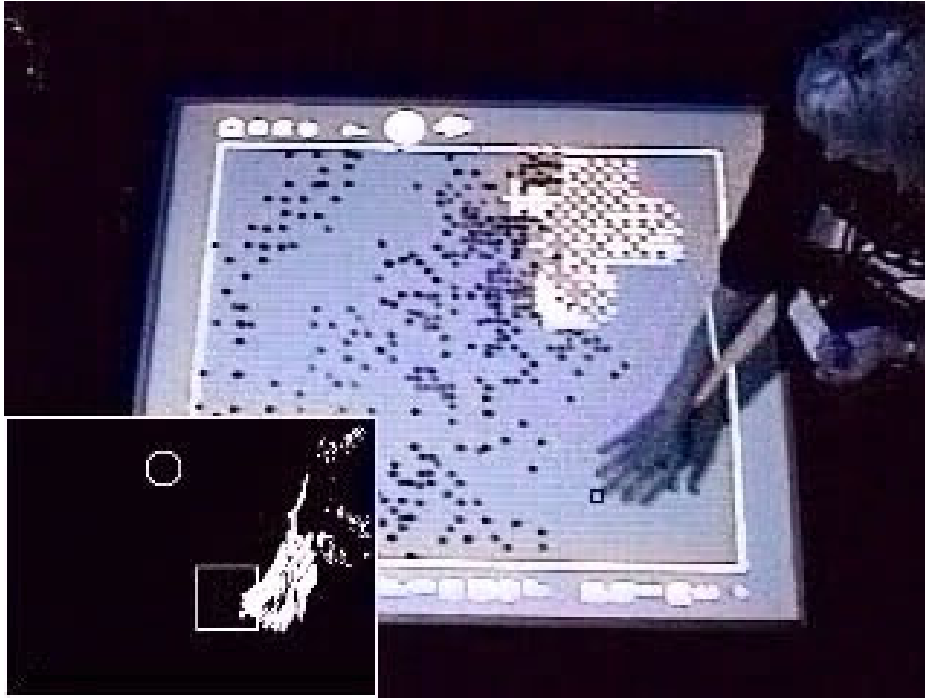
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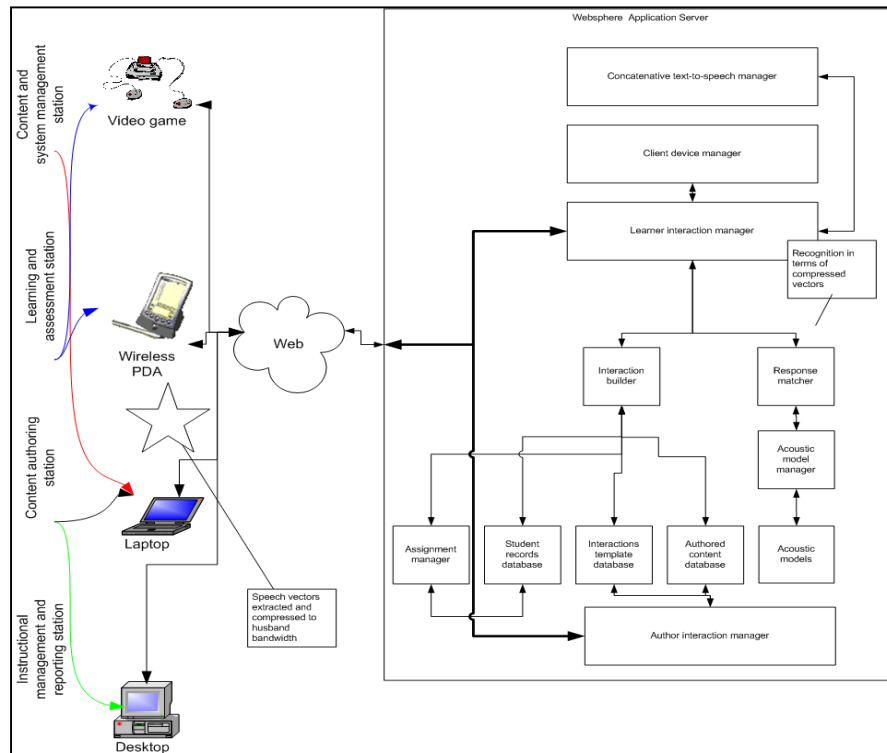
Figure 5

TRANSLATION

While the diffusion of information and communication technologies promises universal access to people, resources, and services for learning, language barriers belie that promise for most of the world's population. For example, the predicted 280 million English-speakers to enjoy the Web in 2004 will be joined by as many as 680 million speakers of other languages, condemned to use it only fractionally [6].

The preponderance of English creates a linguistic equivalent of the digital divide. Sixty percent of the pages on the Web are composed in English, a language used by only 29% of those who use the Web [7]. As the proportion of pages in English has shrunk from 64.55% in 1999 to 60.75% in 2001, this <4% decline implies increases in other languages (e.g., German, 23%; Chinese, 72%; Arabic, 750%). Still, these stunning proportional increases are minuscule in absolute terms.

This linguistic digital divide is present in our local schools too. Language differences bedevil learning in our linguistically heterogeneous schools. More than 325 languages are used at home in the U.S [8]. New York City, for example, enrolls 15% of all its students in English language learning classes; in Los Angeles, 45% [9]. Although eighty percent of these students use Spanish in their homes, other languages shoulder their way to significant frequencies. For example, of the top three foreign languages in New York City students' homes, Spanish leads with 82%, Chinese follows with 12%, and Russian fills the remainder with about 6% [9].

To combat this linguistic Balkanization, teams at IBM Research pursue both grammar-based and statistical approaches to language translation. Spurning a dichotomous tradition of using only one technique (cf: [10]), they build upon the complementary approaches of each. The expense of hand-building frame dictionaries needed for grammatically motivated approaches limits them to translation efforts operating between pairs of languages deemed significant for global commerce. In contrast, statistical approaches can feed off corpora of existing translations to bootstrap a translation system.

IBM Research teams have yoked the power of this hybrid approach translation technologies to its pioneering automatic speech recognition work to produce the Speech-to-Speech Translator [11]. Even though it links the two uncertain channels of speech recognition and language translation, it combines with visual and extralinguistic cues available to those engaged in conversations common to classroom learning.

SUPPORTING REFLECTION VIA E-PORTFOLIOS

Schools are curious institutions when contrasted with learning through apprenticeship: Schools separate students from the places of work and activity where knowledge is being demonstrated and developed, whereas apprenticeship learning takes place *in situ* within the activity context. Ethnographic and historical studies of apprenticeship list impressive advantages for learning, especially for fields where much of the knowledge is process oriented and not highly codified. In apprenticeships learning occurs in context of the tasks being performed; the learner observes expert practice and can imitate it; and the teachers are experts in the domain. How can the distance between the academy and actual contexts of use be reduced? One approach is to help experts document their practice in portfolios.

Portfolios can serve as the basis for reflection, collaborative discussions, and the refinement of tacit knowledge into explicit principles and techniques. Over time these portfolios can help experts evolve a more formal understanding and codification of their knowledge. These are the goals, in part, of the IBM Reinventing Education Project which is seeking to improve teacher preparation. The functional component diagram below (Figure 7) shows how such a system might be organized. The rounded rectangles describe processes (e.g., Organizer, Evaluator), while the rectangles describe data (e.g., portfolios, standards). A time-slice through the system might work as follows: A teacher uses the organizer to create a portfolio. This process involves importing artifacts (e.g., lesson plans and student work), attaching meta-data (e.g., date of origin), and adding reflections and analysis that link artifacts with relevant standards or their professional development plan. Beyond their personal reflection, a teacher can engage the peers and mentors via on-line meetings and interactions. When the portfolio reaches a level of completion it can be submitted for evaluation which invokes a workflow process where it is reviewed. These reviews might lead to changes. Eventually, the portfolio can be published for a broader audience to access. In these ways, hard won "in the trenches" knowledge can be captured, refined, and built-on, thus building a scholarship based on practice and integrated with theory.
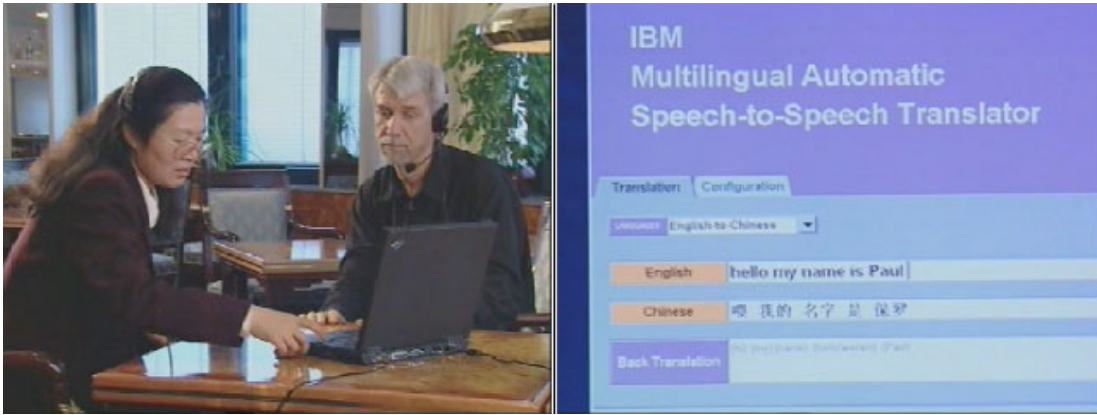
Figure 6
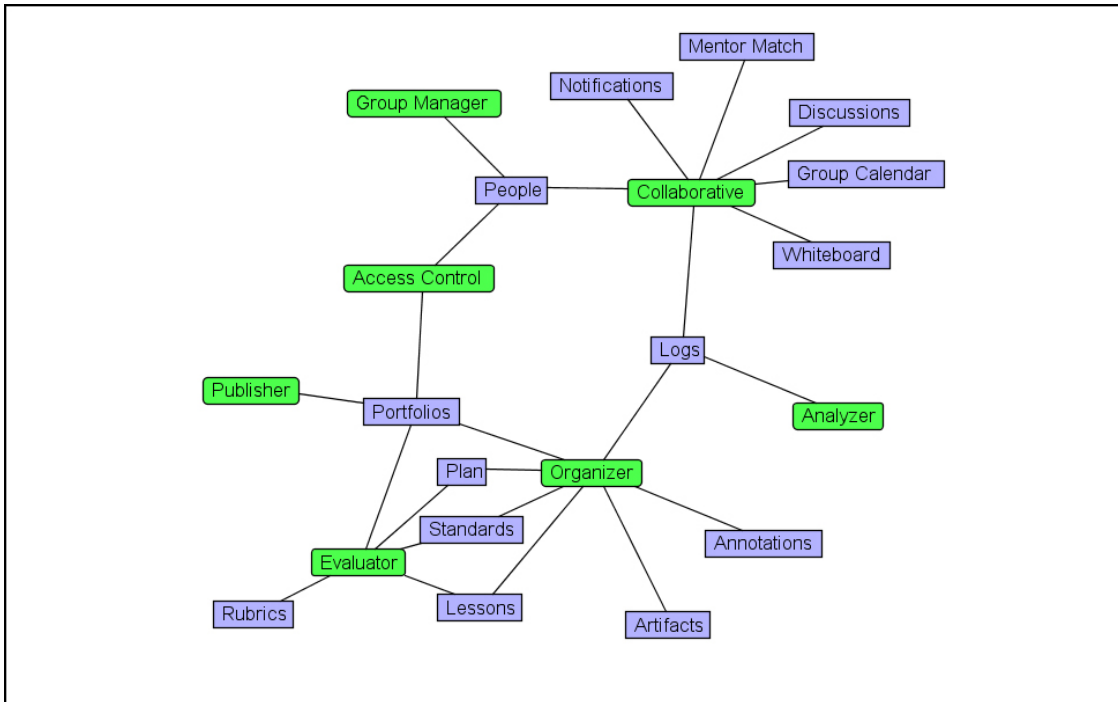
Figure 7

RELEVANT INFORMATION ON DEMAND

Asking questions is at the heart of much learning. Important advances have been made in systems that automatically provide useful answers to certain types of questions. These systems work by analyzing a "document base" or scores of documents that contain the answers the system will provide. For example, a question and answer system (Q&A) might use an encyclopedia as its base input. When a student asks a question, the system retrieves the part of the encyclopedia best suited to answering that question. Currently, systems of this sort work best for "shallow" questions like *Who*, *What*, *When*, and *Where*, but less well for "deeper" questions like *Why (Not), What If*, and *How Did It Happen* [12]. The Figure below shows the architecture of a system that uses predictive annotation (for a more complete description of the systems illustrated in the figure please see [13]). This means that as parts of the document base are analyzed tagged entries are created organized by the type of answers that they might provide. For example, "Benjamin Franklin invented the Post Office", would create a "Who" entry if "Who" were asked about "Post Office". Similarly, when a question is asked, tagged entries are created from it. Answers are found by matching the entries generated by the question to the ones generated from the document base of potential answers.

Figure 8
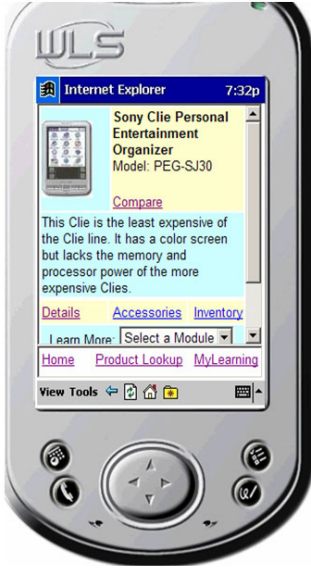
"JUST-IN-TIME" TRAINING FOR RETAIL EMPLOYEES

Performance support is best if it can be provided right where and when it's needed, rather than segregating it to class time instruction. This need is often keen in retail settings, since workers are expected to learn the systems quickly with as little time devoted to learning as possible. Exacerbating difficulties include high e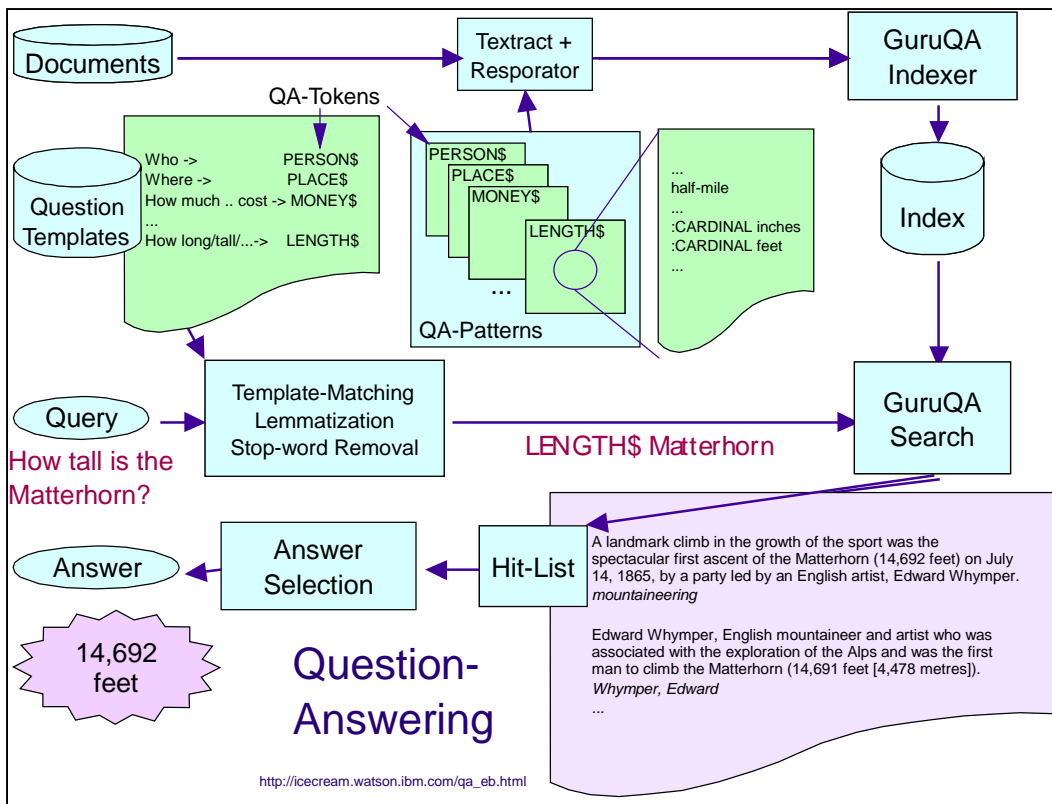mployee turnover, poor motivational structures, timed training time, lack of space in the stores, and short shelf life (with the consequent need to learn about the new stock). Beyond new employee training, all employees periodically require additional training in areas such as safety, security, store layout, company procedures, product information, and employee relations.

Retail requires a multi-tier approach where different technologies are used to address training needs with differing characteristics. Training can be informational, interactive, collaborative, or co-located..

Perhaps the introduction of "just-in-time" information to be the most important new development in retail training that has been missing from prior approaches. However, generating materials dynamically poses a considerable technical problem. Templates can be created to tailor information to various types of learners (senior, out of-college) and to take into account regional considerations. Further, information can be transcoded to accomodate wireless handheld devices with small screens or web kiosks on the floor of the retail outlet.

Figure 9

LEARNING OBJECTS FRAMEWORK

In recent years a substantial standards effort has grown up around creating learning objects that can be broadly interoperable and reusable. This effort could prove a great boon for publishers, corporations, and individual instructors and teachers. However, a key problem is achieving the reuse or repurposing of existing media objects (i.e., content) that were not originally designed for delivery as training. For example, such content includes how-to manuals, textbooks, presentations, or web sites.

The Learning Objects Framework project is developing new models for generating on-demand web-based learning experiences from interchangeable modular learning objects. The framework consists of software components for disassembling, filtering, and automatically processing content to create learning objects and for reassembling learning objects into dynamic courseware. Using this framework, the group has developed a learning environment where users discover and assemble modular learning objects into short, personalized web-based training courses as needed. A key problem is how to maintain coherence among diverse assembled materials. Through this work the project has participated in the development of e-learning standards.
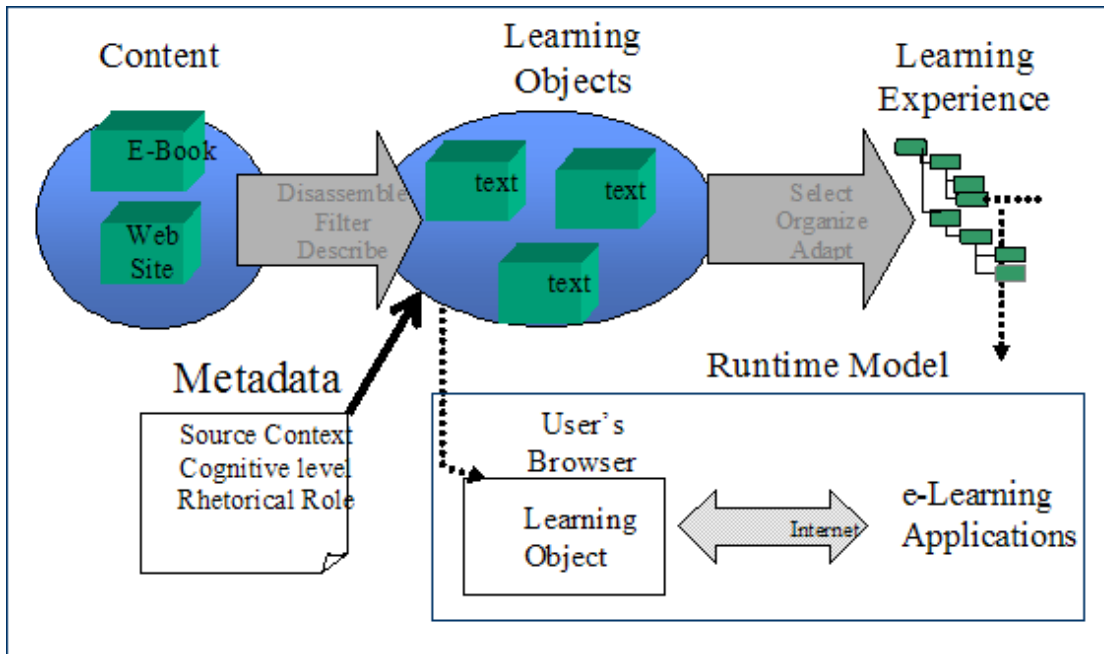

Figure 10

SEGMENTATION OF LEARNING VIDEOS
BASED ON NARRATIVE STRUCTURE

Instructional videos can provide a rich source of learning objects, if the relevant sections could be automatically retrieved. Towards this goal, IBM Research is developing technologies and middleware tools for standards-based e-learning content management to support shareable and searchable learning object repositories with rich media. This effort includes automatic analysis of audio and video for automated extraction of metadata for content tagging.

The video segmentation technology seeks to automatically analyze and segment instructional media using high-level semantics-based video and audio features, thereby enabling effective search and browsing of instructional videos [14]. The analysis automatically detects and separately considers the video's dialogue, narrative, raw footage, and text. The detection relies on common rhetorical conventions. For example, directed narrative is detected by looking for video that is dominated by the speaker's face, whereas in discussion sections the audio track is dominated by the narrator's voice, but the narrator does not appear. Once analyzed and segmented, the clips are formed into learning objects. Thus, user's queries can be addressed with focused video clips that were automatically derived from instructional videos.

The audio analysis is done using a configured IBM ViaVoice system, while custom algorithms have been developed to analyze the video. The system generates both MPEG-7 compliant metadata and Sharable Content Object Reference Model [15] (SCORM) compliant metadata suitable for loading into content management systems.
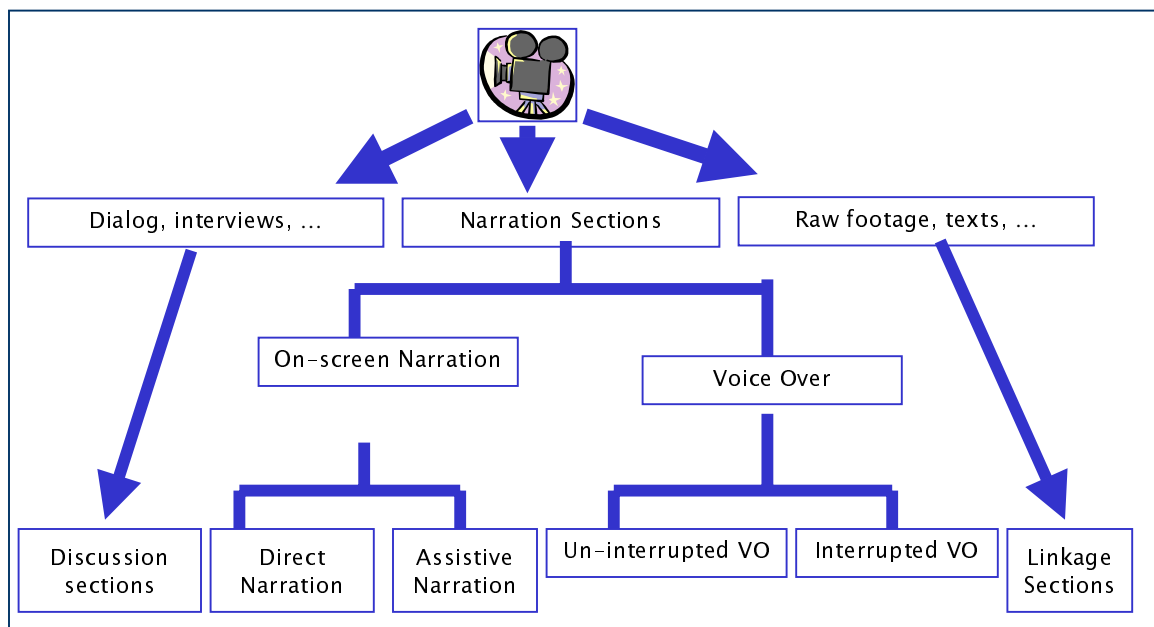

Figure 11

COLLABORATION PATTERNS

Most significant accomplishments are the result of distributed performance amongst many people. Yet, the sheer complexity of large organizations and collaborations make it difficult for us to comprehend and navigate the social networks of which we are part. Visualization systems that map these relationships offer profound advantages for better making use of our social networks, including the choice of whom to ask for help, planning organizational changes, managing collaborative work, and maintaining strong networks of colleagues [16]. In the figure below, a social network is shown based on the co-authorship of patents at a large retail products firm. The green nodes represent patents, while the yellow and blue nodes represent inventors. The blue nodes show a single master inventor and his co-authors. These same inventors are profiled, minus the master inventor and the patents, in the network inset on the right. Showing the social network without the master inventor or "hub node" highlights other inventors who are showing significant leadership and how the lab's social network would look if the master inventor left.
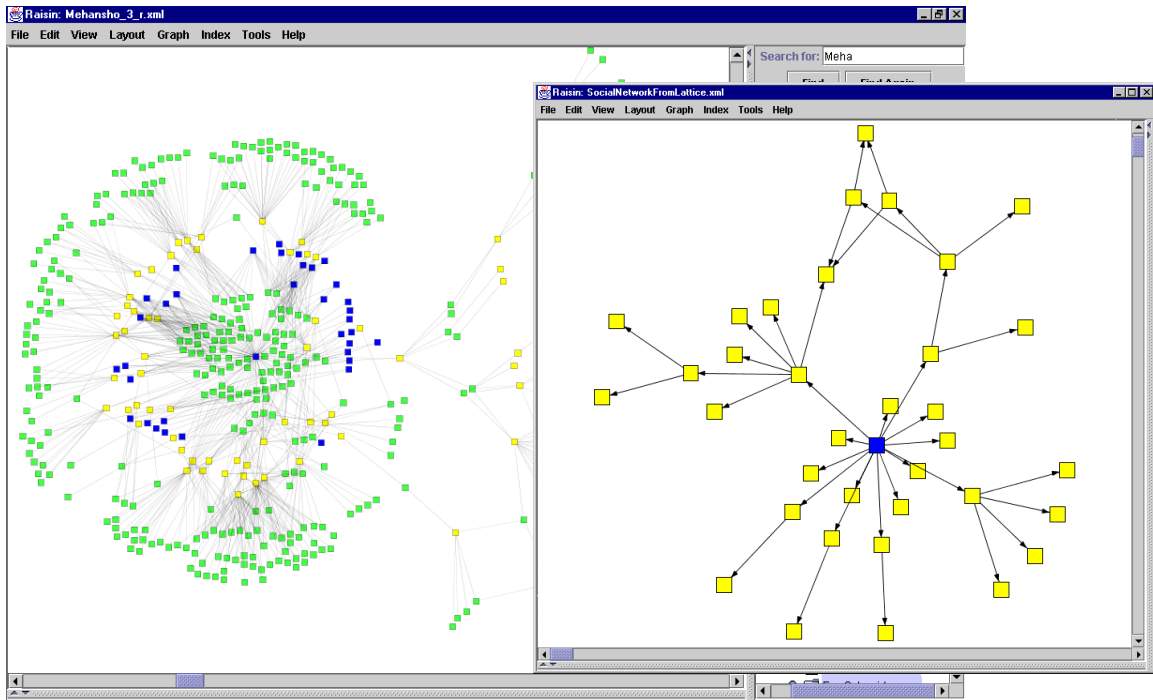

Figure 12

SUMMARY AND CONCLUSIONS

Advanced technologies offer the promise to profoundly impact how we learn and what we need to know in order to accomplish a wide variety of tasks. In reviewing a suite of IBM technologies we have argued advanced technologies are having a profound impact on the context, means, and goals of learning.

In particular, technologies have the ability to transform:

1. *Who learns*: Access to learning can be opened up to a wider population by overcoming disabilities, geography, and language barriers, and providing more universal access.

2. *What needs to be learned*: Technologies change what role people play in the accomplishment of tasks, thus difficult education problems may disappear entirely and the learner can be raised to a new level with increased cognitive abilities.

3. *When learning happens*: Learning can be better integrated with work, so learning occurs when needed. In part, this is enabled by using devices of diverse sizes and abilities, ranging from wireless handhelds to large displays with gesture recognition.

4. *Where learning happens*: The ability of computers to integrate information with our problem context, or to situate it, means that learning can occur on the street, at home, and, in general, integrated with our interactions in the world. In short, learning becomes ubiquitous.

5. *How learning happens*: Translation and language teaching software can help support people communicate using diverse languages. Further, reflective practioners can be provided with more supportive environments for learning from their practice. Finally, improved interaction with large and complex social systems can be enabled by social network analysis systems.

In short, technology can better support anytime and anywhere access to situated knowledge at an increased cognitive depth. These far reaching improvements underline the importance of creatively designing technologies to aid our learning.

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This document contains the proceedings of the Training Workshop on Advanced Learning Technologies and Learning Networks and Their Impact on Future Aerospace Workforce held at the Peninsula Higher Education Center, Hampton, Virginia, April 2-3, 2003. The workshop was jointly sponsored by Old Dominion University's Center for Advanced Engineering Environments and NASA. Workshop attendees were from NASA, other government agencies, industry, and universities. The objectives of the workshop were to provide broad overviews of the diverse activities related to advanced learning technologies and learning environments, and identify future directions for research that have high potential for aerospace workforce development.

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