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The NASA Intelligent Synthesis Environment Advanced Learning Systems Initiative

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Abstract

The NASA Intelligent Synthesis Environment Program vision is to research, develop, acquire, validate, demonstrate and implement revolutionary engineering and science tools and processes for the design, development and execution of NASA's missions in a collaborative and distributed fashion. The Cultural Infusion Element of the ISE Program intends to help bridge the gap between tools, methodologies and systems by developing training approaches and learning environments to fully utilize collaborative capabilities produced by ISE. This effort to bridge the gap will include both "pushing" the advanced learning systems into the Agency to enable program and project managers and employees to use the tools as well as foster the continual learning organization within NASA and "pulling" academia forward to an advanced learning systems capability within academia. Creating effective environments for life-long learning by engineering professionals is essential for the long-term viability of the aerospace industry. This paper will present the overarching objectives of the Advanced Learning System and present a description of the concepts NASA ISE has developed and plans to develop in the future.

Introduction and Background

Advanced Learning Systems refer to an amalgam of dramatically new approaches to teaching and learning – facilitated by breakthroughs in information and communication technology, and stimulated by the pace and complexity of the new knowledge-based economy. Collectively, these systems have the potential to enable significant, possibly revolutionary, improvements in the effectiveness and democratization of education and training. Henry Kelly, President of the Federation of American Scientists, in his speech at the Next Generation Learning Systems (NGLS) Panel meeting, laid out a solid case that the time is now right for advanced learning systems.[1]

In a summary of his presentation, Dr. Kelly pointed out that the shift to the knowledge economy is occurring more rapidly than our ability to provide the needed high-tech workers as well as the continual learning of the current workforce, and the situation poses a potentially serious impediment to continued economic growth in the US. This mismatch between supply and demand for knowledge workers is bidding up the price; there is often more than a 10:1 starting salary advantage for high-tech college graduates over their high school graduate counterparts. With a shortage of skilled labor, companies are forced to invest increasing amounts in training: introductory skills for new and a growing number of replacement workers, as well as upgrading the skills and knowledge base of existing workers. Nearly 80% of the current revenue of Fortune 500 companies are from products or services not in existence 2 years previously and 50% of employee knowledge is obsolete after 3-5 years.

[1] ***The Technology Revolution in Education: Are We Missing the Opportunity?*** Speech by Henry Kelly, President, Federation of American Scientists, Hampton Virginia, September 21, 2000

At the same time, the prospects for successful inclusion of new technologies and learning strategies in education are more compelling than ever before. New computer-based applications are able to provide learning environments that are highly personalized and interactive – actively engaging the learner at just the right level and utilizing his or her preferred learning style. They can simulate a realistic sense of immersion in a rich and flexible learning environment – regardless of the learner's temporal or spatial constraints. Moreover, NGLS enable a much wider variety of collaborations with experts, teachers, and among learner colleagues. These technology-enhanced learning developments now potentially enable vast increases in the number of students who can experience the significant learning efficiencies of one-on-one tutoring environments. [2]

NASA, as one of the world's premiere knowledge-based organizations, has a tremendous stake in this area. More than 50% of the Agency's workforce will be eligible for retirement over the next decade, and this is coming as the Nation's universities are seeing continued declines in Science Math, Engineering and Technology (SMET) graduates. The increasing multi-disciplinary and complex missions NASA and the aerospace industry are planning – all within a low-cost budget environment compound the effects of these trends.

To achieve the ISE goal, many engineering tools techniques and processes will have to perform at substantially higher levels of efficiency. Critical to success of the ISE Program is a fundamental need to substantially improve the Agency's ability to continuously upgrade the skills and knowledge base of its workforce. The ISE's Cultural Infusion element has been given the responsibility for working with other organizations, both within and outside the Agency, to develop advanced education and training methodologies and to serve as a catalyst for changing the entire work culture at NASA. In addition to sponsoring specific advanced learning system development activities, the element charged USRA with a planning task related to the infusion or dissemination of advanced learning systems into the broader educational system.

The infusion of new systems and technologies associated with advanced, collaborative engineering environments requires that various barriers be addressed. Cultural, management and economic issues often hamper the implementation of new and innovative systems, particularly those requiring cross-disciplinary, geographically distributed teams of scientists, engineers and functional specialties. Historically, little attention is paid to the cultural and organizational aspects of implementing new technologies. These types of initiatives will only succeed if the users develop the proficiency to use them. In addition, there is a great need, identified in a variety of reports and journal articles including the "Advanced Engineering Environments: Achieving the Vision" report from the NRC to address the issue of training and development of the existing labor force as well as future users of such systems and technologies in industry and academic settings.[3]

The Cultural Infusion Element of the ISE Program consists of three sub-elements including collaboration and teaming, learning systems and measurement and assessment. Realizing the full potential of collaborative distributed virtual environments entails educating and training engineering and science teams. The CI element intends to help bridge the gap between tools, methodologies and systems by developing training approaches and learning environments to fully utilize collaborative capabilities produced by ISE. This effort will include "pushing" the advanced learning systems into the Agency to enable program and project managers and employees to use the tools as well as foster the continual learning organization within NASA. Further, the tools will help "pull" academia forward to a higher level of learning through distributed cross-disciplinary use of the advanced learning systems. Creating

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[2] B. S. Bloom, "The Two Sigma Problem: The Search for Methods of Group Instruction as Effective as One-to-One Tutoring," Educational Researcher, 13, 1984, pp. 4-16.

[3] National Research Council, *Advanced Engineering Environments: Achieving the Vision*, June 1999

effective environments for life-long learning by engineering professionals is essential for the long-term viability of the aerospace industry. Some of the products being deployed include the joint effort to design and develop an Advanced Distributed Learning system at Syracuse and Cornell University. This system, to be first deployed in the Fall of 2001, will consist of a distributed collaborative multidisciplinary curriculum covering a collection of engineering disciplines using various advanced learning technologies. The first prototype of an Advanced Learning Module, utilizing the latest in voice recognition technology coupled with intelligent agent software to allow learners from remote locations to utilize technology to learn about space flight hardware launch, processing and operation systems.

Discussion

The vision for an Advanced Learning System, or network of systems will aid industry, academia and government agencies in their efforts to restructure their learning initiatives. After decades of evolutionary changes, academic institutions, particularly engineering schools, are due for radical restructuring and adopting new paradigms to meet future life-long learning needs, maintaining the competitive edge for the United States. The proposed concept addresses one of the major problems associated with current “rigid” curricula with strict and narrow disciplines. The Intelligent Synthesis Environment Program is proposing an alternative approach, in partnership with industry and academia, to proceed in this endeavour.

The old concept of an academic institution limited to a campus would be expanded into an advanced learning network consisting of a consortium of academic institutions with the campus facilities augmented by virtual classrooms. This concept integrates three learning environments: expert-led, self-paced, and collaborative (Figure 1).

Figure 1. Three Modes of learning

In the expert-led environment the instructor presents an overview of the subject using advanced visualization facilities and asks penetrating questions to develop learners' critical thinking and creativity skills. The key difference from today's standard method of instruction is that the expert presents the material and basic questions in a very limited amount of time. This enables the learners to explore, on their own or with their classmates, the subject matter. The expert remains available to provide additional, small group or one-on-one learning but the preferred method is up to the individual learner. This is a dramatic departure from the traditional one-hour or more standup lecture. In the self-paced environment, the learner explores the details of the topic using an intelligent tutoring system, perhaps with the aid of a virtual instructor. Facilities are provided to enhance understanding of applicable physical principles and for computer simulation of physical experiments. An expert system is used to test the level of comprehension of the learner and repeat the material, as needed. In the collaborative learning environment, facilities, such as those used for tele-presence, connect geographically dispersed learners and instructors who are from different disciplines working on a joint project. The Advanced Learning System Concept requires a synergistic coupling of advanced instructional technologies. This includes visualization and multimedia with intelligent software agents, virtual reality and advanced human-computer interface/ communication technologies (including perceptual user interfaces and natural language communication).

The technical content used in each environment is generated as modules or knowledge objects. Subject matter experts will develop these knowledge objects in a specific topic working with multimedia and instructional technology expert assistants. The modules are packaged into different disciplinary and interdisciplinary courses and programs. This provides the flexibility for new interdisciplinary programs designed to meet future needs such as revolutionary spaceport technologies. The knowledge objects become reusable as well as flexible for the learners. The key point in this regard is that the learner should be able to pursue only those subject areas that he or she is in the most need to learn. For instance, if an individual is currently knowledgeable of the types of expendable launch vehicles but is unfamiliar with the payload interfaces associated with those vehicles, the individual can access the knowledge object associated with payload interfaces to learn more. This is the concept of "just-in-time" versus "just-in-case". The complete collection of knowledge objects, if provided in their entirety, would be considered "just-in-case". That is, a massive amount of information would be presented "in case" it was ever needed. However, "just-in-time" learning would enable individuals to access and learn only what is needed for the specific effort at hand. In the university environment, this would apply as well, except on a broader scale due to the fact that more learning may be required.

The issue of appropriate technologies for Advanced Learning Environments is important. Whenever appropriate, technology providers would use their beta versions and most advanced facilities in the early formulation of the environments. This ensures that the learning modules will not include obsolete technology once the knowledge objects are developed. This cooperation among industry, academia and other agencies may help in directing the development of the supporting technologies enhancing the effectiveness of the learning network. High tech companies should be partnered with the consortium to ensure that their learning needs are satisfied. Future high tech organizations will by necessity become learning organizations and the use of advanced learning systems will go far in helping to achieve that goal.

Approach

A consortium of the best thinkers in a particular domain is formed (for this discussion, Advanced Spaceport Technology). For instance, this consortium consists of Academic experts in the various subject areas associated with advanced Spaceport systems as well as those from the computer hardware and software development domains. Periodically, the consortium, using collaboration software and hardware, work on development of learning modules and the coupling of the learning module content with advanced technologies for virtual learning networks and collaboration. The consortium completes the development of a "chapter" on a subject, such as space based tracking of launch vehicles that can be rolled up into a "book" on the subject of advanced Range Technologies. This "book" is integrated into an advanced technology collaboration and simulation room or similar facility. The room contains revolutionary cutting-edge hardware and software that will allow collaboration, simulation, expert systems and modeling capability. Within this facility, learners receive initial concept overviews and an introduction to the content. They are then directed to work with the set of technologies provided, such as intelligent software agents, virtual mentors and simulation capabilities. This provides the opportunity to become immersed in range technology systems with a particular emphasis on the application of these technologies in the establishment of a future Spaceport. Evaluation mechanisms and feedback loops are developed such that the modules or "chapters" can be updated, along with the associated collaborative computer hardware and software technologies.

NASA and the University Space Research Association convened a Next Generation Learning System Panel in September of 2000 to bring together national and international experts on the subject of advanced learning systems. This panel meeting included representatives from industry, academia and other government agencies. The participants included professional educators, scientists, researchers and high-level representatives of several software companies. The panel developed a series of findings and released a report (http://phoenix.gvsp.usra.edu/ngls/) describing steps NASA and the ISE Program may take to continue the momentum of attempting to truly revolutionize learning. The strategic goals included:

- Initiating partnerships and collaborations with "like-minded" organizations within NASA and outside the Agency to leverage existing resources and benefit from complementary investments, i.e. serve as an engine for convergence. Establish specific MOA's to clearly delineate areas for cooperation;
- Focusing on deployment and demonstration of early successes, e.g., fund niche pilot projects.
- Fostering methods & incentives for development of space-related educational NGLS modules;
- Seeking to better understand the implications of the predicted convergence of research and education emerging from revolutionary changes in the Intelligent Synthesis Environment and formulating plans and programs in furthering the effective mergers.

A series of tactical objectives were also developed such that near-term progress might be made in the effort. These included:

- Designating USRA, or like organization and the ad-hoc panel as it implements the NGLS university cultural infusion strategies: to provide outside strategic advice, serve as a liaison with other NGLS activities, and assist with development of an ISE resource base;
- Inventory NASA's extant facilities and resources to determine which of them are suitable for 2-D simulation or other low-fidelity application models that can be run on the average university student/classroom PCs;
- Meeting with DoD and NSF to discuss areas for collaboration and look for leveraging opportunities;
- Discussing possible leveraging opportunities for university collaboration among the various ISE Program elements, e.g., establish faculty & student mentoring activities;
- NASA/ISE and a support organization should develop and maintain a database of active NGLS researchers and practitioners for use in downstream initiatives;
- USRA, or similar organization, should maintain a website and establish a listserv and/or newsgroup to promote communication and an on-going dialog between meeting participants and other members of the community;
- Convening a follow on meeting or workshop oriented toward providing the development community access to NASA/ISE facilities and/or other resources;

- Setting up a series of sub-panels or working groups that would be charged with solving critical technical NGLS problems, reviewing candidates for recommended "best practice" awards, and/or for researching technical and cultural infusion issues.

Conclusions

In conclusion, the future of the United States rests squarely on the shoulders of today and tomorrow's learners. Now, more than ever, learners require the latest technologies and the latest methods in order to learn in the most effective and efficient manner. Whether the learners are in an academic setting or an industry setting, they will expect to use the most advanced tools and techniques available to aid in the acquisition of knowledge. The knowledge worker of today needs "just-in-time" learning capability that can be delivered any time and any place in a high quality manner via world-class experts. The NASA Intelligent Synthesis Environment's Cultural Infusion element is partnering with industry and academia in developing advanced learning systems that will explore the role of new technologies and methods in the learning process. The ISE Program has established initial partnerships with a variety of organizations to deliver prototype systems to be made available in the fall of 2001. These prototypes will hopefully set the stage for incremental but significant changes in both university learning methods and knowledge object delivery to the current workforce.