# George Mason University
# School of Information Technology and Engineering

# CNE:
# CENTER FOR THE NEW ENGINEER

August 1993 -- DRAFT (8/11/93)

Peter J. Denning, Director
Daniel Menascé, Associate Director

## Purpose

The Center for the New Engineer (CNE) was established in August 1993 as an ongoing, interdisciplinary investigation into the education of engineers and scientists who are competent at interacting and working in the emerging knowledge society. We hold that engineers have both an opportunity and responsibility to lead society to an understanding that the Internet is not only a worldwide network of cheap, communicating computers, but a place for communities to form and flourish, a place in which human concerns can and will be dealt with. We seek to cultivate engineers of wisdom for this world. Our main strategies are:

1. Design new approaches to teaching engineering based in an interpretation of learning in which knowledge is the capacity for effective action in a domain.

2. Design new approaches to engineering curriculum based in an interpretation of education as an unending process of increasing one's competence and maintaining coherence among all domains of one's life; and as a social process, not merely an individual process, in which one takes responsibility for one's own learning and for the group's learning.

3. Design new approaches to engineering research based in an interpretation that research and teaching are coherent parts of education, and build social and technological mechanisms for maintaining strong links between research and curriculum.

4. Design a collaboration among organizations, mostly regional, to demonstrate a new social function for schools, K-12 and university: jointly transforming the community's new knowledge and new competences into curricula at all levels.

Every project will depend integrally on computing and telecommunications technology to support human practices and concerns. No project of the Center will be considered a success unless it results in new actions by our students, faculty, and others.

## Background

Higher education in America is facing an enormous breakdown. Performance of students on standardized tests has been declining, not only in the absolute but relative to students in other nations. Increasing numbers of students are dropping out of school. Crime, drugs, and discipline problems on campuses are rising. State legislatures have been cutting funds to universities. Private educational services have been established to compete with public. Students, parents, employers, business executives, and public officials are complaining about tuition rising two or three times faster than inflation without a commensurate improvement in the value of education. New books highly critical of the university system, such as *ProfScam* (1988) and *Impostors in the Temple* (1992), have been national best-sellers. Influential commentators say the entire education system is so self-serving and so far beyond redemption that it should be scrapped. In these ways have engineering and science faculty found their traditions and their professionalism under attack.

The system of research that many have said is the hallmark of American universities bears the brunt of many attacks. Critics say that research dominates promotion processes, that the most well-known faculty avoid the undergraduate classroom, that the research benefits only a few graduate students and not the majority of majors, and that research results are published in arcane, esoteric journals beyond the reach of most people. State officials are contemplating restricting or eliminating unsponsored research on campus. In the public mind, research has come to be seen as the cause of the decline in higher education. Criticisms that resonate so widely affect the working lives not only of teachers, but of students.

In "Educating a New Engineer" (1992) Peter Denning proposed that these problems have been caused by massive shifts in the public's understanding not only of research, but of profession, innovation, work, university, and education. The shifts have produced expectations that curricula based on the old understandings cannot meet. He proposed reforms that would adapt our curricula to the new realities.

In "Designing New Principles to Sustain Research in Our Universities" (1993) Denning proposed further that we have allowed research and teaching to appear to be competing enterprises. To reconnect research to the educational mission, he proposed establishing an explicit "feedback path" from research into curriculum. He proposed regional consortia of schools, businesses, government agencies, and other organizations that would share portions of the university curriculum with other schools and would work together to answer the questions of what to teach, how to teach it, and how to cultivate responsibility for education among students.

This center has been founded to work with new interpretations of research, profession, innovation, work, university, and education, and to experiment with practical means of educating engineers within them. The new interpretations are being explored in every one of the center's projects. To the extent that these interpretations are useful, they will become part of the common sense of educated engineers for the twenty-first century.

# Projects

## 1. Exhibitions in the Curriculum

This project aims to design a programming tools exhibition course and a design exhibition course as required milestones in the computer science curriculum, together with redesign of other courses leading up to them.

One of the central themes of the proposals in "Educating a New Engineer" is the exhibition, a public demonstration by students of their capacity for action in some area. Student teams would work on projects, present their work, demonstrate their programs and systems, and defend their work against reasonable questions. They would be evaluated by a panel of judges including two faculty and an outsider.

During academic year 1992-93, a CS curriculum planning committee investigated means to incorporate two exhibition courses in the curriculum within the current time structure and resource limitations of the department. The committee proposed a programming tools exhibition course for entering juniors and a design exhibition course for exiting seniors. The exhibitions would be integrative, demonstrating the student's ability to resourcefully bring together knowledge from several sources into designs for systems. A student can take an exhibition more than once until demonstrating the required level of competence. Two professors tried smaller exhibitions in their courses (software engineering and operating systems) and reported excellent results. An experimental version of the programming tools exhibition is planned for Spring 1994. If the faculty accepts the committee's proposal, a new curriculum including the two exhibitions will be phased in beginning Fall 1994. We expect that other exhibition practices will be developed in other courses leading up to the required milestone exhibitions.

## 2. HPC in the Curriculum

ARPA Contract DABT63-93-C-0026 ($2.9M 1993-96)
P. Denning (PI), D. Menascé (co-PI)

This project aims to create a high performance computing (HPC) laboratory for undergraduates and a set of practices through which faculty transfer results from research domains into the lab. Through joint projects as well as the Internet, the results of this effort will be available to regional and other K-12 schools, and to universities in the National HPC consortium.

A major component of the national HPC program is educating students in the technologies and methods being developed by research groups addressing the so-called grand-challenge questions of science and engineering. ARPA is supporting our center's experiment in developing mechanisms and practices for making the results of HPC-related research available to our undergraduate students and to students in regional schools (initially Alexandria, Arlington, and Fairfax). This is the "feedback loop" described earlier.

The lab facility will consist of three segments. One is the core lab, which is a room containing HPC computers, a connection to the supercomputer facility in the Institute for Computational Science and Informatics (CSI) and a T1 connection to the Internet (designated `cne.gmu.edu`). Second is a set of fully multi-media capable workstations on the desks of all participating faculty; these will be the medium by

which those faculty transfer results from their research domains into the lab. Third is an architecture that will permit students to use the lab without being physically present -- via the network. Lab projects will be staged: students will begin work on a project using scaled down versions of the software in standalone mode on their PCs; they will then connect to the HPC lab server and run tests on their software; and finally they will come in teams to the lab to use the full power of the facilities and demonstrate their results.

All exhibitions and curriculum materials developed around these items of lab software will be recorded in databases on the lab's server, from which they can be conveyed to anyone in local K-12 schools and in the Internet.

A consortium will be formed to share the curriculum materials, engage in joint experiments with distance learning and in K-12/university collaboration, and develop exchanges with regional businesses. (See below for more detail.)

**3. Distance Learning**
CLIN Subcontract to ARPA Contract
Sam Wyman (PI)

This project is a partnership with the Community Learning and Information Network (CLIN), a subunit of the US Chamber of Commerce. CLIN is dedicated to demonstrating dual-use (civilian and military) information and network technologies that allow individual sites to mobilize national educational resources for local education and training. Through a subcontract of our ARPA contract, CLIN will implement the partnership with our Center by setting up a distance learning site in our lab and experimenting with new technologies for instruction. We plan to cooperate with other groups at GMU experimenting with distance learning.

An early experiment scheduled for Fall 1993 is to demonstrate that T1 Internet capacity can be realized by using a channel on the existing TV cable that goes into most schools and homes; this will test an alternative to fiber optic cables. This connectivity will then be used to conduct a workshop with teachers and students planning science-fair projects that would use the Internet.

**4. Educating Engineers to Design Complex Systems**
NSF Proposal ($156K 1993-95)
P. Denning (PI) plus 8 other CS, CSI and GSE faculty (co-PI)

This project augments the HPC lab project by providing for curriculum development of lab modules specifically oriented on teaching students how to make sense of complex systems. Methods from computational science and organizational informatics will be brought in and made available for students' "design portfolios". This will help CS students prepare for the senior design exhibition and other engineering students prepare for their careers.

Engineers are called on increasingly to design complex systems to support work in a widening array of other disciplines. Some disciplines have developed and are using algorithms and architectures in their research that deal effectively with their own kinds of complex systems. For example, computational physics and fluid dynamics have developed powerful solvers for the partial differential equations that

characterize physical systems, and powerful methods of visualizing multidimensional data. Engineers have developed methods of discrete event simulation for distributed systems. Organizational experts are developing cooperative work and workflow management systems to help deal with larger projects whose members are widely scattered. These methods will be made available as six lab modules in the HPC lab:

measurement of scalable parallel algorithms
distributed discrete event simulation
workflow management and tracking
finite element methods
particle simulation methods
image retrieval, recognition, and visualization

A team of co-PI faculty from CS, CSI and GSE (graduate school of education) will work on the first three tasks in the Year 1, and another team of similar composition on the second three tasks in the Year 2. The co-PIs will review all the modules as they are developed. A committee of advisors from other departments of SITE will also provide review and a means of conveying the results to the faculty of other engineering departments. The co-PIs are:

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| Chris Dede | GSE |
| Ophir Frieder | CS |
| James Gentle | CSI |
| Craig Jensen | CSI |
| Menas Kafatos | CSI |
| Daniel Menascé | CS |
| David Rine | CS |
| John Wallin | CSI |

The Advisors Committee is:

| | |
|---|---|
| Dennis Buede | Systems Engineering |
| Gerald Cook | Electrical and Computer Engineering |
| Kathryn Laskey | Systems Engineering |
| Andrej Manitius | Electrical and Computer Engineering |
| Edward Wegman | Applied Engineering Statistics |

**5. Educating Engineers for Action**
NSF Proposal ($499K 1993-96)
P. Denning (PI) + 5 co-PIs

This project aims to design means of responding to four new realities: the demand for more action-oriented knowledge, the increasing number of part-time and adult students, flat budgets, and the need for a regional consortium for education. This will be accomplished through the design of a "collaborative space" of computers, networks, databases, and practices to facilitate students and faculty working together toward exhibitions; through the automation of the routine parts of lower-division curriculum within this collaborative space; and through new means of assessment for students learning in a collaborative, exhibition-oriented environment. The project will be coordinated with regional high schools and businesses so that we can all learn how to coordinate all our efforts to design curricula.

The collaborative space will be implemented by recommending that every student have a PC containing Lotus Notes. Several file servers will be established in SITE cooperatively with UCIS to support this. A teacher will give announcements, notes, and work assignments to a class, receive completed assignments, and coordinate study and project groups, through Notes databases associated with the class. The file servers will also be connected to other compute servers via NFS so that students' personal files will be accessible to them at those servers. (See below.)

The lower division curriculum is a set of three courses that prepare students for the programming tools exhibition. We intend to reformulate this curriculum as a set of milestones that students can pass, at their own paces, en route to the exhibition. Much of this can be automated. For example, there is a significantly diminished need for lectures because a teacher's presentations can be recorded and students can listen at the library or through campus TV and data networks. Grading of programs can be handled automatically by software such as "Ceilidh" from the University of Nottingham. More sophisticated, game-like systems such as those proposed by Roger Schank can be used to prepare students for some milestones. The formal, hour-oriented class schedule would be abandoned and replaced with coaching, tutoring, and guiding student teams with more personal involvement by faculty. There would be scheduled group meetings for all students preparing for a particular milestone. Students would be organized into study groups and for some projects into teams. Coaching would be provided for teams.

With the collaboration of Chris Dede of the Graduate School of Education (GSE) we will develop means of assessing students in this new structure and of involving high school students in the collaborative space with our students and faculty.

**6. Collaborative Space Through Lotus Notes**
P. Denning (PI) and Daniel Menascé (co-PI)
Experiment in ARPA project
SITE/UCIS Equipment Trust Fund Project
Lotus Business Alliance Partner

This project aims to create a "collaborative space" in which groups of students, faculty, and others can form, share work, and take care of concerns. Lotus Notes offers a medium in which documents can be exchanged in a database accessible only to the members of the work group.

SITE has accepted our proposal to establish a network of file servers each containing a Notes server and interconnected with SITE and other campus compute servers by NFS. Notes will be the medium for exchanging email and documents within various workgroups. NFS will be the medium for exchanging files and documents that are either personal or are the results of completed group projects. Since the Notes client residing in a PC connects on demand to a file server only long enough to exchange database updates, and since the PC can be used in a standalone mode to process mail, prepare programs, and edit documents, the connect time between PC and server for these tasks would be reduced by a factor of about 1/100 from current architectures; this would mean a significant effective increase in the capacity of dial-in lines.

This project also responds to the educational need for more groupwork by students. Workgroups will not be limited to GMU students only: teams including students from high schools and regional businesses will also be organized. Organizing students into teams for projects and cooperative study also helps manage the workload faced by faculty so that there is more time spent with students and less time spent by oneself grading papers.

Lotus Development Corporation has designated us as a business alliance partner and has provided copies of the Notes client, server, and API at no charge.

**7. Improving Academic Organization Processes Through Workflow Technology**
P. Denning (PI), Daniel Menascé (co-PI and software manager), Steve Ruth (co-PI)
UCIS/Provost Project
Lotus Development Corporation business alliance partner
Action Technologies business alliance partner

This project aims to demonstrate how technology for the collaborative space can be coupled with workflow management technology to produce significant improvements in academic work processes.

During summer 1993, with support from the UCIS, we have undertaken a university R&D project to use distributed computing to facilitate academic advising, a process whose numerous breakdowns are a constant irritant to students and faculty. The first phase of the project demonstrated that we can import extracts from the university central Student Information System (SIS) into Lotus Notes as databases; we import the transcripts of CS majors, the personal information of CS majors, and the schedule of classes. We designed a database that would show a student's personal information and transcript in the same view. We designed a database that would record notes on advising sessions with students. We designed another view

that would show the department's requirements side by side with the courses completed by students in fulfillment thereof; this view is a facsimile of the graduate checklist form and allows rapid assessment of the student's status and action plans. The second phase of the project will extend the basic system to include servers, test the access control and authentication systems of Notes, and design the structure of databases that can be used to record, and later to export to SIS, the grades of students enrolled in CS courses. The third phase, scheduled for the Fall of 1993 will be an operational test involving both SITE and SBA (school of business administration).

As noted above, we plan additional experiments to use workflow technology to support course administration, which will include the operations of student workgroups and the automated grading of student work.

In addition to supporting the projects of the center, these efforts both support university plans to move from centralized to distributed computing to support campus work processes.

Lotus Development Corporation has designated us as a business alliance partner and has provided copies of the Notes client, server, and API at no charge. Action Technologies has designated us as a beta test site and has provided us with copies of the ActionWorkflow system at no charge.

**8. New Engineer Consortium and Regional School Outreach**
J. Gerstner (coordinator)

This project aims to establish and operate a consortium consisting mostly of regional schools, business, and government organizations, to assist the schools in working together for curriculum improvements and transforming new community knowledge into curricula at all levels.

An inaugural meeting of representatives of Alexandria, Arlington, and Fairfax schools, plus representatives of NSF, ARPA, Congress, OSTP, and representatives of business, was held May 19th at the US Chamber of Commerce in Washington, DC. These representatives agreed to work on a regional project that would use Lotus Notes to establish a collaborative space in which student teams could work on projects with mentors from GMU or from regional businesses.

The consortium will also include nonregional schools who wish to join our experiment and who can serve as an inspiration for our region. The first such is the Val Verde Unified School System, located near Riverside, California. Val Verde is one of the first school systems in the country to be completely wired for high-speed data communications among all schools, and to have ubiquitous NeXT workstations. All school files are accessible through the system from a file server. They are reporting significant educational improvements among their youngsters after just one year of the new system.

During the fall of 1993, the consortium will conduct an experiment in distributed collaboration that will also test alternative technologies for access to the Internet. By cooperating with ARPA and local TV cable companies, we will test a method for using a TV channel as a carrier for IP packets, thus demonstrating that existing cable TV wiring can be used to bring schools into the Internet. Using this as the

connecting medium, we will hold a distributed workshop that will enable students and teachers to embark on science projects leading to science fair exhibitions and feature Internet usage and collaboration with other groups. The workshop will close by the end of the semester and we will check in with the groups to see what kind of results they achieve in their science fairs.

Within a year we will initiate an experiment in which local businesses post descriptions of possible design projects for CS student teams to work on toward their senior projects. We expect that posted projects will be of a type that produces value for the posting organization. The business organizations will specify one of their members to be the client and outside mentor of the student group; their assessments will be a major factor in the team's grade. We expect to recruit more business organizations into the consortium once this program is started.

**9. Reinventing Teaching**

This project is an ongoing investigation of teaching methods that take maximum advantage of new computing and networking technologies and cultivate more effective teaching and teachers. We hold that technologies will automatically make teaching better: we also need to work with the practices and skills of the faculty, and with the students as well.

One opportunity for obvious innovation is in the practices of student group work. The Lotus Notes and workflow projects will provide a technological medium for communication and coordination among group members. About half our students are part-time and the number is growing. Groups that could not collaborate before because of work schedules can soon collaborate over the network.

Another opportunity for innovation is in the practices of the classroom. Lecturing will become outmoded because professors can record their presentations and demonstrations and students can view or use them at their convenience. The class sessions will become workshops in which the students work on projects, receive coaching, and engage in group work. There will be more emphasis on students "inventing the material for themselves" and less on "presenting information to students" and the role of the teacher will shift to supervising the processes of invention.

Many students fall into bad moods when faced with new challenges. These moods, which include anxiety, frustration, resignation, and resentment, can significantly interfere with students' learning. Many faculty have not incorporated into their classroom practices an awareness of these moods and approaches for dispelling them. The diminution of lecture presentations will allow the faculty to devote more time to this. The best teachers of the department can serve as teachers for the others.

**10. Sense 21**
P. Denning

The purpose of this project is to establish a growing network of students and faculty devoted to developing a new shared (common) sense that would enable them to be much more effective engineers in the 21st century. The new sense will be based in new interpretations of communication as coordination of action, in moods as

pervasive biolinguistic phenomena, in learning to learn, in producing solidarity in groups and communities, and in cultivating historical sensibility. These basic interpretations will be used to develop new interpretations of the role of engineers in society and of the meaning of engineering education.

In Spring 1993 Denning offered an experimental course called "Designing a New Engineering Common Sense" that began the investigation above. At the end of the course, the students said they desired to continue working and learning together, so Denning formed a club called Sense 21. These students have been meeting monthly and have been conversing by email daily. The immediate goal is to improve the course for offering to a larger group of engineers in Spring 1994 and to establish a network of students and faculty who can teach the new interpretations to others.

An example of the phenomena that current engineering curricula do not teach is coping with the growing complexity and increasing speed of change of the world and the systems engineers are asked to design. Although engineering teaches many powerful analytic and planning methods, the world often does not always give the engineer time to complete a plan before action is needed. What does the engineer need to know in order to be able to act effectively in the face of uncertainty and incomplete planning?

## Participants

### Consortium (cne-consort@cs.gmu.edu)

The Consortium for the New Engineer consists of representatives of Alexandria, Arlington, schools in Northern Virginia and of schools in Southwest Virginia; representatives of Federal agencies such as NSF, ARPA, and OSTP; representatives of Virginia State Education agencies; representatives from regional business organizations; and observers from distant districts, notably the Val Verde Unified School District near Riverside, California. About 30 individuals are currently on the mailing list.

## Business Partners

Various business partners have already joined the center's projects. Lotus Development Corporation has accepted GMU as a business alliance partner and has provided a number of Notes licenses at no cost to enable our Notes projects to proceed. Action Technologies will also provide, at no cost, a beta test version of its ActionWorkflow system that will be used in our workflow management project.

We will be inviting regional businesses and government organizations to register design problems with us that students can select for their design projects. A partner will act as the client of the project, and their assessments will figure strongly in the team's grade.

## Other GMU Groups

We have the active participation of the Institute for Computational Science and Informatics (CSI), the Graduate School of Education (GSE), and the School of Business Administration (SBA) in our center's activities.

## Advisor and Executive Committees

`cne-exec@cs.gmu.edu:`

The executive committee of the project consists of Peter Denning, Daniel Menascé, Joe Gerstner, Alan Schultz, and Sam Wyman.

`cne-advisors@cs.gmu.edu:`

The advisors committee consists of Ophir Frieder (CS), David Rine (CS), Ed Wegman (AES), Kathryn Laskey (SYST ENG), Lynn Fontana (GSE), Menas Kafatos (CSI), Chris Dede (GSE), Dennis Buede (SYST ENG), James Gentle (CSI), John Wallin (CSI), John O'Connor (ENGLISH), Jerry Cook (ECE), and Andrej Manitius (ECE).

`cne-observers@cs.gmu.edu:`

The observers group consists of various faculty from GMU who wish to be kept informed of the progress of projects.