



**Calhoun: The NPS Institutional Archive**  
**DSpace Repository**

---

Faculty and Researchers

Faculty and Researchers' Publications

---

2004

## An Interview with Peter Denning: Building a culture of innovation

Denning, Peter J.

---

An Interview with Peter Denning: Building a Culture of Innovation  
<https://hdl.handle.net/10945/35472>

---

This publication is a work of the U.S. Government as defined in Title 17, United States Code, Section 101. Copyright protection is not available for this work in the United States.

*Downloaded from NPS Archive: Calhoun*



Calhoun is the Naval Postgraduate School's public access digital repository for research materials and institutional publications created by the NPS community. Calhoun is named for Professor of Mathematics Guy K. Calhoun, NPS's first appointed -- and published -- scholarly author.

**Dudley Knox Library / Naval Postgraduate School**  
**411 Dyer Road / 1 University Circle**  
**Monterey, California USA 93943**

<http://www.nps.edu/library>

# Articles

## AN INTERVIEW WITH PETER DENNING BUILDING A CULTURE OF INNOVATION

April 2004 | BY [UBIQUITY STAFF](#)

|

To view the full citation in the ACM Digital Library please click [here](#)

Peter Denning talks about transforming practice in a community, cognitive blindness and finding dead cows

Peter Denning teaches students at the Naval Postgraduate School how to develop strategic, big-picture thinking about the field of computing. A past president of ACM (1980-82), he has been involved with communicating our discipline, computing, to outsiders since 1970. He has contributed several innovations that shaped the computing field: he invented the working set model for memory management, developed a theory of virtual memory, promulgated operating systems theory, co-invented operational analysis of system performance, co-founded CSNET, and led the ACM Digital Library team while chair of the Publications Board. He is an ACM Fellow and holds five major ACM awards. He just completed a five-year term as chair of the ACM Education Board.

**UBIQUITY:** Let's talk about innovation. What do you think people have a hard time understanding about innovation?

**DENNING:** That's a good question. What I hear most commonly from people is the notion that innovation means a new or novel idea. Some people add that the idea flows through a pipeline of research, development, prototyping, manufacturing and marketing. The pipeline transforms it into a product or service with an economic impact. Now in this model, a lot of people think that the work of innovation is the creation of new ideas, and that the flow to market is the destiny of great ideas. To teach innovation, therefore, is to teach creativity and problem-solving. I realize that's a simplistic description. I'm focusing on the misconception that innovation is the creation of new ideas.

**UBIQUITY:** Then what is a better description?

**DENNING:** An innovation is a transformation of practice in a community. It is not the same as the invention of a new idea or object. The real work of innovation is in the transformation of practice. In this definition, community can be small, as in a workgroup, or large as in the whole world. A transformation of practice in the community won't happen unless the new practice generates more value to the members than the old. Value may not be economic; it may be pride, reputation, health, safety, freedom. Many innovations were preceded or enabled by inventions; but many innovations occurred without a significant invention.

**UBIQUITY:** Give us some examples.

**DENNING:** A wonderful book published last year by Ilkka Tuomi, called "Networks of Innovation," does the best job I've seen in revealing the difference between the idea-model of innovation and the way innovation actually works. Tuomi focuses on three major innovations that have widely

influenced how people think about and use computers: Linux, the World Wide Web, and the Internet. Not one of these three exemplifies the "pipeline" model I just described — the creation of an idea, the systematic R&D, and an economic return to the inventor. Take Linux for example. Linux is a public domain equivalent of Unix. It has been completely developed, changed, and maintained by a large community of volunteers. Those volunteers did not do it for economic gain. Linux didn't start with a new invention; Unix already existed. It didn't start with a research paper. It started because one guy, Linus Torvalds, was concerned about making a high-quality public-domain version of Unix available to the masses. Torvalds found a lot of friends to help him. Linux turned into a major social transformation. IBM has embraced Linux and includes it on computers it sells to its customers. Even Microsoft has made adjustments to its business practice on account of Linux. Nobody doubts that Linux was an innovation, and yet it doesn't meet the conventional idea of what an innovation is. The same thing is true with the World Wide Web.

**UBIQUITY:** Tell us why it's true with the Web.

**DENNING:** Tim Berners-Lee demonstrated the first browser on a NeXT computer in 1991. He invented it as a proof-of-concept for his idea of document sharing by a worldwide web of interlinked documents. In many ways, the browser was unremarkable because it used many existing technologies. Berners-Lee worked tirelessly to make his technology useful so that people would adopt it in their work. In 1994 he founded the World Wide Web Consortium, W3C, to be a forum where people could reach consensus on web services and standards, so as to promote the ongoing development of the Web. Berners-Lee never waived from his conviction that the basic software for the Web should be public domain and free to everyone. He repeatedly turned down opportunities to start companies that would allow him to profit from his own invention. He was not in it for economic gain. And much the same is true of the Internet. The Internet started as ARPAnet, a DoD research project aimed at facilitating resource sharing among DoD computers. During the 1980s, ARPA cooperated with the National Science Foundation, which through a lot of volunteer labor created CSNET and then NSFNET, the backbone of the modern Internet. They also had a consortium, the Internet Society and its Internet Engineering Task Force, that kept the software in the public domain and fostered consensus on protocols and data standards. The bottom line is that all these innovations don't fit the conventional model. The common feature is a transformation of social practice in a community.

**UBIQUITY:** Why do you insist on the notion that innovation is transformation of practice? Why not just have two kinds of innovation: technology innovation and process innovation?

**DENNING:** I'm interested in innovation as a standard practice of computing professionals, especially of their leaders. I want to know how to teach innovation. If all I do is teach creative problem-solving, I won't produce innovators. If I teach them how to effect social transformation aided by computing technology, I can. To call an invention "technology innovation" might make a company's advertisers happy, but it won't help my students learn the practice of innovation.

**UBIQUITY:** It's possible to say that an idea failed (the phrase is actually "it didn't get off the ground"), but does it make sense linguistically to say that an innovation failed? If it's an innovation, doesn't it mean that it succeeded?

**DENNING:** That's an interesting point. When we say an idea or invention failed, we mean that nobody did anything with it. It didn't "go anywhere" — didn't take anybody's interest. If we pointed out a community who changed their practice, we could say, "Well, look at that. An innovation has taken place!" This is an after-the-fact observation. There's no question of failure if it's

an innovation: it's something that has actually happened. But there's still a way the word "failure" can be used in a discussion of innovation.

**UBIQUITY:** And what is that?

**DENNING:** A failure to meet people's expectations — in other words a mismatch between people's expectations of an innovation and what actually happens, or a mismatch between an idea and the innovation to which it's supposed to contribute. In fact, Peter Drucker cites the unexpected as a rich source of opportunities for innovation. Many businesses have jumped on a sideline that turned out to be popular with customers, or abandoned a mainline that was not. An example of this sort happened to me in the early 1990s at George Mason University. I was chair of a committee to draw up an acceptable use policy. We hit on the idea of an analogy of a driver's license to use the GMU network. In our public hearings, we learned that students would not buy this idea — it seemed too easy for system administrators, whom they did not trust, to revoke their license. Instead, they favored a "stopit" system being used at MIT, which allowed for someone bending the rules to retreat gracefully as long as they did not repeat. We threw out the driver's license idea and adopted the stopit idea. The resulting policy was widely accepted by students and the few infractions were easily handled by the stopit system. We produced a transformation of that community's practice, but it wasn't the change we initially expected.

**UBIQUITY:** Let's think of how the word innovation might be used in various contexts. For example, if someone says that's an innovative educational program — such as your own computer science program at the Naval Postgraduate School — what is really being said there? What makes a program innovative?

**DENNING:** Adoption of a new CS curriculum is a change of practice by a small community, the CS faculty and its students. The new curriculum is an innovation in our local community. Your question refers to someone comparing the local CS program with all CS programs, finding that the local program differs from the norm, and concluding that the other programs would benefit from adopting the practice for themselves. And there's also an implication that the program is doing something more valuable than the old way of doing things.

**UBIQUITY:** There is always a suggestion that innovation is better, that it's progress in some sense; yet in spite of the fact that innovation is generally thought of as a good thing nowadays, it's not perceived that way by everyone in the world. There are those who think that innovation is just muddying the waters. Some are Luddites, some are anti-globalization activists, and there are no doubt many others. What would you say to such people?

**DENNING:** According to my interpretation, innovation won't occur if the community sees no value in the proposed new practice. A developer of industrial parks may have been successful in many industrialized countries but finds unexpected resistance to his proposal for an industrial park in a developing country. Maybe the locals don't want any US companies in their country. Maybe they want an industrial park constructed and run by local companies without the influence of US culture. What appears as progress in one community appears retrograde in another. No change of practice will occur unless they see value. Value is not necessarily monetary: they might see they can make money from an industry park, but they don't want US culture to gain a foothold in their country.

**UBIQUITY:** The world of the arts has the old war-horse slogan, "Art for the sake of art," which presumably means what it says; is there an equivalent phrase in the world of business and organizations and society that could justify innovation by saying "change for the sake of change"? Could it be said that change itself is a sort of innovation, and that tends to be good for people

to change, to stir them up? That's a management theory that's been floated from time to time. Is that right or wrong?

**DENNING:** This comes back to the question of what produces value for people. There are certainly some — the progressives perhaps? — who value changes and will work to promote them just because they are different from the status quo. But I think that when it comes to change that affects them directly, most people tend to be conservative and not embrace it unless they see some other value than the change itself. People embrace institutions, the purpose of which is to codify practices that are of great value and resist changes. At the bottom it's simple: no value, no change; no change, no innovation.

**UBIQUITY:** Out of curiosity, how is change perceived at your own institution, the Naval Postgraduate School? Are the students, for example, biased in favor of change? And/or the faculty?

**DENNING:** As with all else, it depends on where they see value. There's a prevailing attitude to make things better if the opportunity arises and the change does not compromise the military values of honesty and integrity. The Chief of Naval Operations, in concert with the Secretary of Defense, frequently mentions his desire to foster a "culture of innovation". He's referring to the objective of transforming the fighting forces from traditional strategies and tactics to new ones consistent with a "network centric" philosophy. Getting flag officers to embrace a new approach to war fighting, qualitatively different from what they've known their entire careers, can be a difficult sell.

**UBIQUITY:** How do they typically use that phrase "the culture of innovation"?

**DENNING:** The Navy leadership is asking everybody to contribute toward positive changes without having to wait for explicit orders from their leadership. In a culture of innovation, people will have a habit of constantly looking for ways to improve things. The Navy leadership wants the Postgraduate School to teach officers how to participate in a culture of innovation. That creates an educational challenge for us. What does it mean to be a practitioner in a culture of innovation?

**UBIQUITY:** And what have you concluded?

**DENNING:** We see two kinds of practice contributing to a culture of innovation. One is organizational processes: management values, rewards, prohibitions, encouragement of new ideas, encouragement of risk-taking, and the like. There is a substantial literature about how organizations can be innovative. The other kind of process is personal. What are the personal practices one must have to succeed in a culture of innovation? We believe that without a foundation of appropriate personal practices, it's very hard to get the organizational practices to work. Since changes to personal practice often entail personal discomfort, we find it more challenging to teach this aspect than the organizational aspects.

**UBIQUITY:** What headway have you made?

**DENNING:** We're still experimenting with this. We are finding that our students all have a strong interest in the success of their master's projects. They would like to organize their projects to have an impact and even to stimulate useful changes after they graduate. We are showing them how the personal practices of innovation can help them achieve their thesis goals. We believe that, with this return on their investment, the students will embrace any changes they need to make in their personal practice. We've taken a lot of inspiration from Peter Drucker, whose 1985 book, "Innovation and Entrepreneurship," is a real gold mine of insights into how innovation really works.

**UBIQUITY:** People's reaction to the book?

**DENNING:** Very supportive. Drucker discusses the practice of innovation, which consists of five steps: locate an opportunity, analyze it, assess your community's receptivity, maintain a focus on a simple central core idea, and exercise leadership. It is easy to map this on to the process of doing a master's thesis. It is also easy to step back and see that the thesis itself is an exercise in analysis as part of a larger process of innovation that they can continue after graduation. In spite of its apparent "age", this book is not the slightest bit obsolescent. It gets to the fundamental issues behind innovation, and talks about how individuals and organizations can embrace the process.

**UBIQUITY:** How do people find opportunities for innovation?

**DENNING:** Drucker lists of seven sources of innovation: the unexpected, incongruities, process needs, change of industry structure, demographics, change of mood or perception, and new knowledge. The first four show up as challenges to the internal operations of an organization; the other three are external and are subject to competition from other organizations.

Let me give you an example that has led to a project that may produce an innovation that the Navy and DoD are actively seeking. I discussed before the Navy's interest in adapting its warfighting doctrine to a highly networked world. Navy leadership has been pushing various initiatives in networking, all the way down to the networking found in the workplace. They have been meeting more resistance than they expected. They are perplexed that people are not simply "following orders" to implement the changes in networking. In the Cebrowski Institute, this does not surprise us because changes in networking affect the details of how people work and carry out their missions. Many officers experience conflict if they perceive that following an order to change networking would adversely affect other orders to carry out their missions. To us, there is an incongruity between the leadership's desire for networking changes and the difficulties of effecting it through the traditional giving of orders. We see this as an opportunity for an innovation. We have proposed that the DoD establish a "Global Consortium for the Grid." GCOG would be modeled after the World Wide Web consortium, and it would be a forum for network engineers from around the DoD to reach consensus on protocols, data formats, architectural concepts, and interoperability standards. We believe this will facilitate changes because everyone will have an opportunity to reach agreement on changes before they take effect. A consortium of military commands and their academic and industry collaborators would be an innovation within the military structure. It is being embraced and we may be able to launch it by the end of 2004.

**UBIQUITY:** It seems that the common denominator of your observations is that the innovator needs to be aware and to listen to people, in order to know be able to understand when something is above customer expectation or below customer expectation.

**DENNING:** Bingo! That's exactly right. Awareness is key. Drucker shows you where to point your eyes, but without awareness you will not see. Not everyone who encounters an unexpected success or failure sees therein an opportunity for innovation.

**UBIQUITY:** Your use of the word "Bingo!" raises this question: What is it that allows some percentage of people to have the capacity for thinking "Bingo" — that is for having such insights? What is it that gives some people a natural innovative style or an ability to think in innovative ways — and what is it that apparently prevents other people from doing so?

**DENNING:** To answer that question, let me return to my initial distinction between the creation of a new idea and the process of producing change. Many people can indeed be more creative in their production of ideas — they

can break loose from their standard habits of thinking, they can try out different observers, they can create new games. People often find these creative processes to be uplifting. The invention of a new possibility can lift one's spirits and can be fun. Look at the great moods people enter after a brainstorming session. A creative person can help someone who's stuck in a negative mood by proposing new possibilities for them. Obviously, people who can open new ways of thinking, and help us see what was previously invisible, can make a big contribution. But there's a world of difference between being in a good mood about a new possibility and actually making it happen. Helping people actually make the change, is where the real work is, and that's a different skill set. My answer to your question, therefore, is that people who have trouble accomplishing innovations may lack knowledge of the process or of a foundational skill.

**UBIQUITY:** What's next after identifying an opportunity and creating a new possibility for addressing it?

**DENNING:** Drucker says: Analyze it. Can you make a business or project plan to accomplish the result? Can you identify the costs, the benefits, the risks, the responses to risks, and the main milestones? Can you lay out your engineering or science approach? Only after such analysis can you decide whether you want to go forward; you might well decide that you can't go forward. The analysis phase is very important. After analysis comes listening. Drucker says go out into the community in person, discuss your proposal, and assess their receptivity. Are they open to your proposal? Enthusiastic? Apathetic? Hostile? What changes must you make to secure their buy-in? Are they so unreceptive that you might as well drop the project?

**UBIQUITY:** What's next — or does the listening phase go on forever?

**DENNING:** After you have concluded that your plan is sound and is likely to be received well, you get to execution of the plan. But Drucker does not call this the execution stage; he calls it the focus stage. That's because, during execution, you need to keep everyone's attention on a simple core idea behind the change and keep from veering off into interesting distractions. Many projects fail because their leadership cannot maintain focus and their energies become scattered. Moreover, if your proposal looks too complex, people will give up on it. Maintaining the focus requires clear thinking, discipline, and a mood of ambition and confidence.

**UBIQUITY:** So simplicity gets included in the successful innovator's skill set?

**DENNING:** Yes. Look at the skills needed to accomplish these steps: awareness, focus, persistence, listening and blending, simplicity. In addition, you need a skill of making powerful declarations and compelling offers. You need to be able to lead the team who will help you carry out the plan. You need to be constantly in a mode of learning. And it helps to have a sense of destiny — a sense that you are acting on behalf of a purpose larger than yourself. These are all different skills from the inventor's skills. One day a friend, who happened to be in a cynical mood said, "All these things add up to salesmanship. I know a large number of shysters who successfully hawk bad products because they are good salespeople. You are making me very pessimistic because you are saying that good ideas may not stand on their own but must be sold!" As much as I would like good ideas to sell themselves, the world does not work that way.

**UBIQUITY:** In that light, you've suggested in various ways that the ultimate test of an innovation is that it does in fact add real and substantial value. The shysters can't deliver that.

**DENNING:** Exactly. Value is everything. The ultimate test is whether people actually engage in a new practice. They won't do that unless there is real value for them.

**UBIQUITY:** How should people think about value, and how they should look for it?

**DENNING:** Value is an assessment made by a customer that an offer is worth taking up and giving up something else to have. One common way to tell that people value something is to observe them paying money to have it. But payment is not the only measure of value. People will do many things for reasons other than money. When we started this conversation, we discussed how some people might not want a US developer to build an industrial park in their country because they place a higher value on preserving their culture and tradition than on making money. Economic value is meaningless in that context. It takes a great deal of awareness and listening to discern what people deeply care about and value. They may be unable to articulate it!

**UBIQUITY:** Is there any hope of making a bridge to overcome such a difference in values?

**DENNING:** That's a skill of its own. I call it listening and blending. Others call it "going for the win-win." Going for the win may mean you have to be prepared to walk away if you can't negotiate a win-win. Can the industry-park developer find an offer that preserves the culture and tradition and lets them run their own businesses? Such an offer might appear as valuable in that country.

**UBIQUITY:** In these examples, are you suggesting that there are skills the individual must master to enable the process of having an impact?

**DENNING:** Yes. I call these the "Personal Foundational Practices of Innovation." They are enablers for being able to do the various parts of the innovation process. They are: awareness, focus and persistence, listening and blending, declarations, destiny, offers, networks and institutions, and learning.

**UBIQUITY:** How do conclude these practices are foundational?

**DENNING:** I have talked to many innovators and read the personal stories of many others. As I listened and read I paid attention to what sorts of personal qualities and characteristics they had that enabled them to accomplish their goals. These are the ones that emerged from this process. I have been teaching students about them since 1993.

**UBIQUITY:** Why is awareness a foundational skill?

**DENNING:** That's easy. The first part of the innovation process is seeing an opportunity. You need to train your awareness so that you see things that you would have previously missed. Drucker's Seven Sources are a guideline for much of this practice. But just knowing those seven isn't enough. You can point your eyes in the recommended direction and still see nothing because of a cognitive blindness. That means that your brain is stuck in an interpretation of the world in which the sensory data about the opportunity just don't register. Cognitive blindness means there is something you cannot see and you cannot see that you cannot see it.

**UBIQUITY:** Any examples of this?

**DENNING:** Last summer I attended a lecture by John Seely Brown, formerly the Director of Research at Xerox PARC. He spoke about how "tunnel vision," his phrase for cognitive blindness, prevents people from seeing opportunities for innovation. In tunnel vision, one gets so focused on a single thing that one cannot see alternatives. To illustrate, he said he would show us a video clip. "In this clip, you'll see some people in white shirts passing a basketball among themselves, and also some people in black shirts passing a basketball among themselves. I'd like you to tell me how many times the ball changed hands among the white shirts." When the clip finished, he asked for the number of



white throws. The vast majority said 16 and he thanked them for their ability to focus and get the answer. Then he said, "How many people saw the gorilla walk through the middle of the game?" In that whole room of a thousand people only 3 raised their hands. Almost everyone else looked completely puzzled. What gorilla is this man talking about? He ran the video clip again and, sure enough, a man in a gorilla suit sauntered into the game, beat his chest, and sauntered out. The gorilla is there, carrying on in the middle of the game like this, for about half the clip! John Seely Brown concluded that many of us miss an opportunity — the gorilla walking through our game — because we get focused on something and our attention does not register the new possibility.

**UBIQUITY:** So how do you teach people in your own program how to do something new?

**DENNING:** We ask them to read books like "Conceptual Blockbusting". We ask them to read Drucker on the seven sources and do exercises of systematically going down a checklist and asking if they see an opportunity in each category. For those who want to go deeper, we recommend that they learn a physical practice such as a martial art or dancing, which trains awareness of many senses at once. We recommend to some that they learn a meditative practice, which also helps train awareness. There are many ways. However one trains awareness, the training happens in the doing of a practice, not in the reading of a book about the practice. The practices sharpen the awareness and produce a habit of mind that makes it possible for someone to see opportunities for change.

**UBIQUITY:** So the real key to innovation is learning how to be aware and to maintain some sense of wonder about everything you see?

**DENNING:** Almost. Awareness is one of several keys. You need all the keys. Awareness impacts the other foundational practices. For example, if you cannot be aware of the cues that reveal a person's deep concerns, you will have trouble with listening and blending and with offers. One of the best antidotes to tunnel vision is to talk with other people who don't see the world the same way you do; people who see the world differently can show you what you cannot see yourself. A practice of collaboration supports awareness.

**UBIQUITY:** OK, let's say you've really trained your awareness and you now see many opportunities. How do you decide which one is the most fruitful?

**DENNING:** Some years ago, my teacher and friend Fernando Flores told me a story about how Louis Pasteur was recruited by French farmers to help them understand why their cows were dying and find a way to prevent their deaths. The farmers were desperate and they thought Pasteur's quirky ways might help them see something they had missed. Pasteur was initially not sure he could help but, after he had examined cow feces, he announced he could. At the time he was formulating his germ theory of disease and he could see small bacteria in the feces. He identified the agent that was causing the cows to die and invented the anthrax vaccine to protect healthy cows. He received powerful financial backing and recognition for his research from France's industry leaders. Flores said that the best innovation opportunities are the dead cows. When you are looking for opportunities, look for the dead cows. Help people figure out how to prevent them from dying.

**UBIQUITY:** You have been involved in several major innovations. You were one of the four founders of CSNET. What were the dead cows and how did CSNET revive them?

**DENNING:** In 1979 I became head of the Computer Science department at Purdue and immediately found myself immersed in a survival question: How might Purdue CS maintain its position in the top 10 CS departments in the face of rising competition? As I talked to colleagues at other universities —

who had similar concerns for their own departments — I discovered that there was a strong current of concern among CS departments about the widening gap between the "haves" — the few universities with ARPAnet access — and the great majority of "have nots". At the time the ARPAnet was restricted to about 150 DoD contractors and there was no way that the DoD was going to let another 120 universities join. So the dead cows were the gap between the ARPAnet-connecting the remaining universities, and the threats to survival and well-being that we all felt in our guts. I joined Larry Landweber, Dave Farber, and Tony Hearn to produce a proposal to NSF to clone the ARPAnet and connect all the CS departments together. The project started in 1981 and by 1985 we had linked all the departments and become self-supporting through a dues structure. Early on, we helped NSF and ARPA reach a cooperation agreement that permitted CSNET originated traffic to flow through ARPAnet. That was momentous — it opened up non-government traffic flowing through government networks. Later we helped the two agencies negotiate an even more momentous agreement that permitted CSNET to include industry labs in the CS research community. This opened up commercial traffic flowing in the network. In the late 1980s, many alumni from the CSNET project populated the committees NSF established to help create NSFNET, which became the backbone of the modern Internet. A lot of people don't realize the crucial role that CSNET played in enlarging the network, establishing policies for traffic between government and non-government nets, and opening the nets to commercial traffic, and in providing experienced network people to help NSF accomplish the larger task of starting the Internet backbone.

**UBIQUITY:** Early in your career, you invented the working set model for memory management and developed a theory of virtual memory. Virtual memory is now in every computer and operating system. What were the dead cows when you came to the area?

**DENNING:** I came to MIT as a PhD student in 1965 when they were launching the Multics project. The idea of building automatic paging systems to manage memory was about five years old and was being embraced by major computer manufacturers including IBM, RCA, GE and Burroughs. Much to their surprise these companies were finding that multiprogrammed virtual memory systems were exquisitely sensitive to a sudden collapse of performance they called thrashing. These systems could suddenly transition from a mode of high throughput and low response to a mode of low throughput and high response time. No one understood why this was happening or how to control or prevent it. It threatened the nascent time-sharing industry and the large investments of these major computing companies. All those thrashing systems were the dead cows. I became fascinated by the problem and set out to explain it and find a method for preventing it. Multics leadership endorsed this work because they did not want their time sharing system to meet the same fate. In late 1966 I had an "Aha!" insight that became the working set model. I was able to show how to build a memory manager around working sets that would not be susceptible to thrashing. By 1970 I had integrated all the scientific knowledge about virtual memory into a single theory that gave computer and operating systems makers confidence that they could include virtual memory in their systems at no risk of thrashing. Today virtual memory is in every operating system and most people just use it without being aware of its presence.

**UBIQUITY:** And did those personal foundational practices help you with these innovations?

**DENNING:** At the time, of course, I was not aware of those practices by name. But I did have a good nose for dead cows and in the two cases we just discussed I was consumed by a sense of destiny in pursuit of solutions. I'm referring to a sense of being pulled along by a higher purpose. When I look back, I see that I was able to maintain focus, be persistent, listen to critics,

blend with and incorporate their concerns, make declarations and offers, network with like-minded people, help create institutions to preserve the innovation, and constantly feed my appetite to learn more.

**UBIQUITY:** You have been recognized for other innovations besides these, but we don't have time to explore them. Perhaps another day.

**DENNING:** It has been my pleasure.

---

## COMMENTS

### POST A COMMENT

Your Name (Required)

Your E-Mail address (Required)

Comment (Required - HTML syntax is not allowed and will be removed)

Post

