Chapter 9

Problem Solving in the Work World

Defining the Problem

"Defining the problem through marketing is absolutely critical," says Dean Spatz, founder and CEO of Osmonics, Inc., in Minnetonka, Minnesota. "As engineers, we can make the greatest product in the world, but if it doesn't meet a human need, then it's basically worthless. There's no sense in developing a solution to a problem that doesn't exist in the first place."

Engineers at Osmonics apply reverse osmosis to processes as diverse as concentrating sugars for maple syrup processing or purifying water for dialysis machines. The idea for the company began in the early sixties with a jar full of brackish water. Spatz and his Thayer School classmates were given the sample and told to find a way to make it potable. Reverse osmosis was a relatively new concept then, so Spatz and his team worked to apply the process to desalinization. After successfully using membranes to separate the brackish component out of the water, Spatz looked at other applications of the process, such as concentrating sugars. Shortly after finishing his degree at Thayer School, he formed Osmonics and set up a reverse osmosis unit on a friend's sugar bush—several acres of maple trees devoted to maple syrup production. The fuel savings the first year alone were more than 60%.

Over the years, Osmonics engineers have discovered a variety of markets for the reverse osmosis process, and the company has grown steadily from a small business with a single market focus to a $150-million company with diverse markets. Spatz attributes at least part of his success to the way he has applied the precepts of engineering problem solving to the inner workings of the company. He says that he often has to teach problem solving to young chemical engineers whose traditional textbook problem solving has not prepared them for defining and redefining a problem.

Spatz believes in problem solving for students at every level. He understands the challenge for teachers. "The instructor has to help students define the project without getting in there and saying, 'You do this, you do that.' More like a coach. That's a tough job for the classically trained teacher. But the whole idea of coaching is preparing someone to do the work. The coach can't get in there and play. From a business standpoint, it's no different. That's what separates good managers from the ones who may have some leadership ability but can't let others do the job."

Technical Specifications and Marketing Constraints

Another Thayer School graduate, Cameron Jones, worked with Thayer School instructor Sydney Alonso to transform a different laboratory problem into a business. The original problem was: How can digital electronics improve music instruction? Young electronic composers at Dartmouth College worked on Moog synthesizers, the instrument of the day, but these were unwieldy instruments to set up and, worse, had no memory. Alonso accepted the music department's challenge and built the world's first digital synthesizer; Jones, a musician as well as software expert, programmed it.

"I knew what I wanted the machine to do because I was a musician," remembers Jones. "The computer technology available at that time offered only very, very primitive sounds—triangle waves and pulse waves." Alonso agrees that what they were doing was, in those days, just barely doable. Generating sound for digital processing was hard enough, but taking into account such musical characteristics as harmonics or attack and decay, gave the problem added complexity.

The enthusiasm of Dartmouth music students led Alonso and Jones to think that there might eventually be a market of professional musicians. In 1976, they left Thayer School and founded New England Digital, Inc., makers of the Synclavier Digital Music System. For a number of years, the company remained a technology-driven company. A musician could pose a problem, but the emerging technology could only do what it could do. "Here's this incredibly primitive technology," says Jones, "and the question is, can we do something useful with it and will somebody pay for the product? O.K., let's do that. And then two or three years later it's making feeps and boops, and we ask, are any of these sounds something people would find useful? And so it kind of grew."

Jones reckons it was ten years before the technology was sophisticated enough to make the instrument useful for full-scale music or audio production. "By 1985 there was a wide palette of technologies available," says Jones. "And at that point, you had to apply business constraints as well as engineering constraints to the problem. Instead of, here's the technology, who might be able to use it? it was, which market do we want to go after?"

Through the mid- and late 1980s, the company produced the Rolls Royce of digital music systems and sold it to customers such as Oscar Peterson, Laurie Anderson, Stevie Wonder, Frank Zappa, Michael Jackson, and Sting. As the array of digital audio technologies grew, the customer became an important source of new problems. Pat Metheny, master guitarist, heard the quality of the Synclavier and asked whether a guitar could be the user interface; within a year, sounds of the Synclavier were emerging from Metheny's strings. Pianists who questioned the feel of the non-responsive electronic keyboard pushed the company to develop a keyboard sensitive to both velocity and pressure. Eventually the company branched into digital audio recording, marketing to Lucas Films and other film post-production studios.

As New England Digital became a market-driven company, it became a prime example of how communication between problem solvers and their customers keeps a developing product on the cutting edge. By designing a machine to be used by creative people—musicians, sound technicians, film directors—New England Digital could take advantage of the imaginations of their customers. Customers, using the Synclavier in idiosyncratic ways, told New England Digital engineers what might make the machine work even better. The engineers, of course, continued to look at the existing technology and devise new ways to push it further. The core problem—how to improve the Synclavier—was in a continuous state of redefinition.

Both Alonso and Jones believe problem solving is an essential ingredient of the education process. "Compare the approach that just spends all its time in the classroom working on artificial problems" says Alonso. "If it's not something you're going to use, it can be pretty dry. You get motivated kids and then treat them to a methodology more applicable to ROTC or prison or something, they soon get unmotivated. But set them to real problems and some kind of spark may happen."

Teamwork and Leadership

Leadership, says William Boddie, Chairman of the German division of the Ford Motor Company, is not dictatorship. "You've got to find out how to motivate. You cannot coerce people. Well, you can, but the results may not be what you want. If you've got something you want done in ten minutes, coercion may be the best way, but if you've got something that's going to take three years, you're dead if you try coercion. People who learn that early in their careers are the most successful."

Ford engineers have traditionally worked on function-based teams. Chassis engineering, for example, might be applied to any car in the company's line. Ford teams are now oriented toward specific customers—Taurus drivers, Escort drivers, or drivers of the F-Series Truck. Each team focuses on the whole product instead of the part. The workers not only understand how their jobs fit into the larger picture, they also have objectives in line with the customer's objectives, making the customer a partner in defining the goals.

Boddie believes that an understanding of group dynamics and interpersonal skills is really the key to leadership. "When you get into a situation with a group of people who are all different, you have to have a way to get every member of the group to want to do the same thing. If you're the leader, you have to make each individual want to do what you want to do. Figuring out how to do that, how to get them to want to do what you want them to do, is the most important skill a leader can have."

The structure of the group, although it may develop out of teamwork, is also the responsibility of the leader. When Boddie first came to Ford, company structure was based on the military. "One of the things that you find in the army is that you have some doers and then you have the watchers and checkers. Because doers tend to rebel against the management style in that type of organization, you have to have watchers and checkers to make sure that they aren't too far out of line. If you're in the army, where you have an infinite number of resources to apply, that's no problem. If you're in a competitive business where other companies don't need watchers and checkers, then you're going to go out of business if you can't figure out how to do your job at the same resource level the other company achieves."

Boddie notes there are times when leaders must make unilateral decisions. The goal is to achieve consensus as best you can, but the leader is ultimately responsible for the team's productivity. "I always try for consensus," says Boddie. "But some decisions could take the group in the wrong direction. It's the leader's job to see that and make the right decision."

Teamwork, then, is a balance of consensus and leadership. "There's no such thing as a highly productive team that doesn't have a good leader." And how does one foster leadership in young people? "I think you learn by doing," he says. "I don't think you learn by being told."

The Customer in the Design Process

Paul Stokstad, like Dean Spatz, is founder and CEO of a company born as a student project. PASCO Scientific, Inc., a company in Roseville, California, designs laboratory kits, computer interfaces, and science accessories for secondary and post-secondary physics courses. The company's first product—a kit to replicate Robert Millikan's 1912 oil-drop experiment—began as a high school physics project; then, while at Dartmouth, Stockstad turned the Millikan experiment into a product to sell. A second project—developing a streamlined version of the unwieldy electrometer of the day—became the second product for what would eventually become PASCO.

Stokstad counts on customers to make the company successful. Some bring ideas and beginning designs for new products. Others test products in the classroom. Stockstad calls teachers "PASCO's conscience." He knows engineers love to put in as many features and gadgets as possible just because they can. When a teacher says, "That's going to confuse the daylights out of my students. I want one knob and I want it to do only this," PASCO listens. Never mind that the other features can be incorporated without adding to the cost. The teacher has the last word on the reality of the classroom.

For example, thanks to feedback from teachers, the low-friction carts that PASCO sells for studying dynamics and motion have spring-loaded wheels. If a student steps on one, it flattens to the floor so the student can't skateboard. "This is what you get from teachers," says Stokstad, "things that an engineer might not think of. But once the teacher says, 'This is what I want, these are my needs,' then you can apply the engineering skills."

Stokstad is in touch with the reform movement in science education and fully supports it. He chuckles about a student intern who was given a piece of equipment which had been the subject of complaints. He was told to read the manual, set it up, and run the experiment ten times. "So the student leaned over," remembers Stokstad, "and he says, 'OK, now what's the number I'm supposed to get?' 'No, Vern, just do the experiment.' He said, 'I know, but what's the correct answer?' And that said something about most of the science courses he took."

Stokstad supports the idea of students starting with experiments instead of lectures. Learning Newton's laws and then proving in the laboratory that Newton was right is not, in his opinion, very effective. "Your mind isn't open, you aren't looking to learn something, you're simply trying to confirm." He believes that the computer is driving us to move beyond the cookbook laboratory. "Computer plots out 200 points, you can see what it is. All right. Now let's do some mathematical curve fitting. What would be a proper mathematical model? So you start with a real-world experiment and work back and find that, well, interesting, Newton had this same conclusion x number of years ago."

Brainstorming in the World of Finance

"A truly innovative solution," says Peter Fahey, a Thayer School graduate and limited partner at the New York financial firm Goldman Sachs, "is the one that departs the most from the norm. So you have to get crazy before you come back to sanity and reduce something to practical."

An investment banker advises companies on different financial tasks, such as how to raise money or how to accomplish a merger or acquisition. Problem solving, according to Fahey, is problem solving whether you are inventing a device or facing a financial question. Fahey looks at any situation and asks, how can we improve on the way it has been done previously? "Always seeking the better solution, never being satisfied with traditional solutions—that's the idea."

Fahey believes that the key to superior problem solving is the step of brainstorming alternative solutions. He asked colleagues "to suspend logic for a while and generate a number of alternative approaches to a given problem without regard for whether any approach is feasible. It doesn't matter whether the ideas are even really that good; brainstorming simply serves to generate a wide array of approaches. And it is important to generate them because, although Idea #37 may not make any sense, it will often lead your thought process on a path different from one it might otherwise have followed. Later you are able to make the idea into a feasible solution." Brainstorming, then, is important not for the number of ideas generated but for the way some of them affect thinking.

Fahey has established a number of formal and informal mechanisms to introduce the engineering approach to problem solving into his firm. In the beginning, colleagues would say, "Oh, that's a crazy idea!" but Fahey persisted with the point of view that no idea was crazy. Eventually colleagues came to accept the value of identifying a broad array of alternative solutions. Clients, although they may not have known why, found themselves advised to take innovative financial actions. They never knew that a successful idea was the result of the suspension of logic and generation of "crazy" ideas, but, as Fahey says, "Brainstorming is the essential, intuitive part of the process that leads to superior, innovative solutions."

Communication

Communication is the key to good problem solving, according to Dennis Drapkin, a Thayer School graduate and partner at Jones Day Reavis & Pogue in Dallas, Texas. "The lawyer's stock and trade are words and language. The ability to communicate is essential. One thing we look for in hiring people is how well they can communicate, how well they can decipher from the world what it is that's important and then turn around and communicate it to someone else."

Drapkin believes that legal problem solving is no different from problem solving in any other field. "What's the process of what I do? It didn't become completely clear to me for many years, but lawyers, like engineers, are professional problem solvers. I really don't think there's much difference in the process."

Lawyers need to be able to communicate to other specialists in their field and to translate the specifics of a case for those without legal training. "You have to be able to do both," says Drapkin. "You have to be able to explain technical content to someone who is technically adept and you have to be able to explain it to someone who isn't but who happens to be your client. Make the complex and arcane parts of the Internal Revenue Code comprehensible to anyone, for example."

It's a skill that requires practice: reading and writing critically and analytically, being able to separate the meaningful from the meaningless, communicating orally and in writing. Students who describe their projects clearly and succinctly in writing and before a review board are practicing the skills of a lawyer, skills that will stand them in good stead in any field, from business to medicine to teaching to aviation. Drapkin applauds all efforts that foster good communication skills. "Being able to read and write, being able to comprehend knowledge from a variety of sources and knowing how to find it—these skills are vital to any profession."

The Interdisciplinary Approach

Charles Queenan, a 1978 graduate of Thayer School, applies engineering problem-solving skills to the world of environmental and energy consultation. As president of Putnam Hayes & Bartlett, an economic and management consulting firm based in Washington, D.C., Queenan underscores four aspects of engineering problem solving that serve him well in his consultation work. First is teamwork. "We do virtually all of our work in teams," he says, "often with several members of a client's organization. The trick is to arrange teamwork so that group thinking can go other than in a lot of different directions and still reach good conclusions. It's an art."

The second element Queenan believes essential to problem solving is brainstorming, an "exchange of ideas unfettered and unconstrained. And this is a lot harder to achieve in a real-life context."

Interdisciplinary work is Queenan's third—and most basic—element. Environmental problems need to be addressed from the perspective of several disciplines—public policy, economics, technical, legal. There are always tradeoffs to consider. Assessing the risks in life sciences, understanding hydrogeology or geology in order to assess the dangers of transporting contaminants, understanding the legal requirements with respect to different solutions that might be applied to a problem—all these issues must be addressed. Bringing different disciplines together in the same team, then, is essential.

Clear and careful analysis from the different perspectives is the fourth element. "Once you have an understanding of why you need to solve this problem or why that technical issue is important, you can do the analysis."

Teamwork, brainstorming, interdisciplinary grounding, and analysis—these are all brought together each time Queenan takes a client's case. The mission might be to help the client company evaluate its major potential environmental liabilities, such as hazardous waste sites, and then to help them develop a strategy to solve the problem. The team might include environmental attorneys, engineering consultants, and Queenan himself, with his mix of engineering and business experience. The success of a team comes from what each member brings to the forum and how together they create an atmosphere where they can risk, as Queenan puts it, "the brilliance of dumb ideas."

Queenan sees a tension between brainstorming—"the freedom to say something stupid"— and the interdisciplinary expertise of the brainstormers. "If any one of us were to say something stupid too often, we wouldn't be here. You can't suffer fools too often." On the other hand, ideas that at first blush appear not to make a lot of sense often help the thinking process. And when ideas are generated in a forum firmly grounded in multidisciplinary expertise, the team needn't fear going down a blind alley.

"You can have a great exchange of ideas, many of them perhaps stupid, and if you can bring to the issue the right disciplines and the right analysis, the right grounding in theory and in fact, you can really get somewhere." Each potential solution is tested against constraints articulated out of the expertise of the different team members. Analysis relies on everyone's perspective. At the end of the day, the best solution may not be the one any single team member might advocate but rather the one all can agree solves the problem with the least harmful impact.