news story

ProductDesign and Development

Thinking In Prototypes

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Trial and error still plays a key role in product development. The answer is not to avoid mistakes but to make them early and often.

By Bart Eisenberg, Technical Editor

Dennis Boyle of the Palo Alto, CA, firm IDEO sifts through a box of prototypes for the Palm V handheld computer - one of the most successful "palmtops" ever produced. The device was half as thin and four ounces lighter than the previous generation. But what first seems like a leap of engineering turns out to be a series of incremental steps. The prototypes are rough; none resembles a working model. Each demonstrates a few designer ideas, so that the collection seems the physical equivalent of a brainstorming session. How to attach the stylus to the case? One prototype does it magnetically. Another uses a flexible nickel-titanium base. A third, closer to the final mark, slots the stylus into a groove.

None of the prototypes used to develop the successful Palm V handheld computer resembled a working model. By producing many rapid but rough prototypes, mistakes were flushed out early in the design process. "Fail early, fail often" is the creed at the IDEO design firm. IDEO encourages its designers to get mistakes to surface early in the development process, when they are less costly.

"Once you have ideas, or more likely a set of competing ideas for solving a problem, you have to render them in a way that people can experience," Boyle says. "Prototyping is ultimately about getting the people who are going to use the product, who will pay for it, to experience it - even in a crude way - so that they can articulate what they like and don't, or at least so you can infer such by their actions."

The proliferation of design models has actually changed how CAD software is used at the design firm Design Continuum. Onscreen renderings are used to describe the product visually in a realistic way, but the output is now a physical prototype. A 2D screen rendering isn't enough. In fact, CAD drawings aren't even printed any longer.

Prototypes once proved that the design concept was actually mechanically viable. While that's still part of the goal, prototypes have now become a sort of three-dimensional sketchpad. The effect of producing so many rapid but rough prototypes is that mistakes are flushed out early in the process. "Fail early, fail often" is the IDEO creed. "We try to get the mistakes out early on, when they are less costly," Boyle says. "If the project is not generating masses of prototypes, including many that clearly won't fly, something is seriously wrong."

These days, CAD combined with rapid prototyping has put design iterations on fast-forward. But the iterative process needed to produce a breakthrough product can take years. Such was the case with the now common zipper, which took more than two decades of iterative design before the familiar interlocking teeth emerged. "The zipper was really a revolutionary idea, going from eyes and eyelets and high-button shoes to something that would fasten with just a zip," says Henry Petroski, who has chronicled the engineering history of other common devices including the paperclip. "Big design leaps take time. Fuel cells, another design leap, were used in spacecraft back in the 1960s. Yet they are still not fully integrated into automobiles. The process has taken even longer than the zipper."

Lenny Lipton is now the CEO and principle researcher of StereoGraphics, a pioneer in 3D video displays. But years ago, Lipton wrote the song "Puff the Magic Dragon" with friend Peter Yarrow. There are parallels between song writing and product development. In real R&D, you pull an idea out of thin air and nurture it into a product. It's a creative endeavor.

Trial And Error: Limited But Not Abolished

The zipper's long gestation period has a message for contemporary mechanical engineers. CAD tools and rapid prototypes have compressed the design cycle but have not abolished it. Designers dislike the phrase "trial and error" - it sounds so uncontrolled and wasteful. There are methodologies galore that help limit the scope of the design iterations so that the process doesn't veer out of control, breaking the budget. But some trial and error remains at the heart of new product development. That's especially true for smaller companies who are not trying to protect an established product niche but hoping to create something entirely new. In doing so, design engineering shares a methodology with people engaged in the arts.

"The novelist writing a book, the sculptor chiseling a statue, the musician composing a concerto, the engineer designing a bridge, and the theater director giving her actors the first crude stage blocking all allocate their resources so that improvement in their product is by successive approximations," wrote Billy Vaughn Koen in his book "Discussion of The Method: Conducting The Engineer's Approach To Problem Solving."

Koen sees the engineering method everywhere: All creative endeavors are a form of problem solving in which perfection is not possible. The problem is unknown; the resources are limited. The best we can do is take a successive number of stabs at the problem within the resources we have available to us, based on what we know. When, as is inevitable, we don't succeed, then we must try, try again. Koen says that Picasso's early sketches for his famous painting "Guernica" is "absolutely identical to what the engineer is doing - getting to the goal by successive approximation. As my MIT professor told us as students, 'always get in the ballpark first. Then find the diamond. Then look for home plate.' He wanted us to design that way."

Lenny Lipton is the CEO and principle researcher of StereoGraphics, a pioneer in 3D video displays. But while a student at Cornell, Lipton once banged out a poem in his friend Peter Yarrow's apartment. The two thought it had the makings of a song, and for months they bounced the words back and forth. The result, "Puff the Magic Dragon," took three years to complete.

"Day to day, most of what I do is still trial and error," he says. "Obviously, you need some wisdom, based on experience. But mostly, I try different things, find out what works, and stop doing what doesn't work. Trial and error is a pragmatic form of hope. Mistakes are inevitable, but hope tells you if you try enough things, something will work out. One thing is for certain - if you don't try, if you don't have the guts, you will fail."

Lipton thinks that when conducting R&D that is worthy of the term, iterations are inevitable. "In real R&D, you start off with an idea out of thin air and nurture it into a product. It's a creative endeavor. Stereoscopic imaging is a nascent field. We make something exciting that people have never seen before, that will make the world a better place - at least by a bit. I like springing something new on the world."

Prototypes Replace CAD Printouts

The firm Design Continuum near Boston maintains a 4,800-square-foot design shop. "If I don't see a design iteration rendered overnight, then it's useless to me," says designer Jack Gundlach. He says that the speed of the turnaround, the coarseness of the models, and their resulting low cost have changed the way prototypes are used. Prototypes are physical, but the way engineers now use them, they act as pages from a sketchbook, a means for making a decision, but not necessarily a keepsake. "We now throw prototypes away like so many pieces of paper. They are extremely valuable in decision making, but they aren't precious objects anymore."

The proliferation of design models has actually changed how CAD software is used at the firm. "I don't think we've printed a CAD drawing around here in years," Gundlach says. "We'll do onscreen renderings that try to describe the product visually in a realistic way. The 3D data is created on the computer, but the output is now a physical prototype. A 2D screen rendering isn't enough. It can fool you. You really need to experience it, to have the sense of scale that only a 3D object can give you. How big was that handle you just put in there? How big

was that access for the knob on the showerhead? How are you going to know it feels right - not just for you but for different people?"

Rapid prototyping has become a form of dialogue between designers and their creations. But what the prototype "says" isn't always what designers want to hear. Greg Moores, vice president of new product development at Black & Decker's DeWalt professional tools division, recalls prototyping a new router that included a depth setting mechanism. "The way the depth setting works is critical - it must be both easy to adjust and repeatable if you disassemble the unit or change the bit." After designing the prototype in CAD, the designers took prototypes into the field, trying to answer the obvious questions: Is it easy to use. Is it comfortable? But the news that came back surprised the designers. Users perceived the prototype to be fragile even though it wasn't. "We actually beefed up the design so that the users would perceive it to be strong enough, even though we knew it already was strong enough to survive a drop test."

Could this data have been anticipated in CAD alone? That's the goal, says Moores, but it's an elusive one. "We tell engineers to try to anticipate as many things as you can by putting yourself in the user's shoes, but ultimately, we never really know what they're going to say. For that reason, engineers who take prototypes home and actually use them tend to thrive in our environment." In the hands of a craftsman, a power tool, after all, is not merely a machine but an extension of the soul - no less so than a violin in the hands of a violinist. The balance, weight, and control placement all matter, and an engineer who knows this chemistry first hand is in a better position to improve it.

Moores remembers designing a coffee maker at a time he didn't drink coffee. "OK, I thought - I can design a mechanism that takes the water's temperature and holds a filter. But I really didn't have the same connection I did with a woodworking product I designed in the early '90s. I brought the prototypes home in succession and actually made several pieces of furniture that are still in my house. Everyday, I would take that prototype back to work with a sure sense of what needed to be changed. There was an emotional attachment. I was my own end-user."